Communications Operating Concept and Requirements for the Future Radio System

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EXECUTIVE SUMMARY

EUROCONTROL and the Federal Aviation Administration (FAA) have initiated a joint study under a Memorandum of Agreement through Action Plan 17 (AP 17) to identify potential future communications technologies to meet safety and regularity of flight communications requirements, i.e., those supporting Air Traffic Services (ATS) and safety related Aeronautical Operational Control (AOC) communications.

This document identifies the future ATS concepts and then uses Air Traffic Management (ATM) operational requirements and airline operating concepts expected to be implemented in the highest density airspace regions to specify requirements in the Communications Operating Concepts and Requirements (COCR) document.

The COCR is used to determine candidate data communications technologies – existing or future – that can meet these requirements. The COCR is independent of any specific aircraft and ground radio communications technology. The physical implementation of the radio components of a communication system are collectively referred to as the Future Radio System (FRS).

The COCR considers two main phases of communications to support Air Traffic Management. The first phase (Phase 1) is based on existing or emerging data communications services and completes around 2020. Initial steps under this phase are starting in some regions now. The second phase (Phase 2) represents a new paradigm in the use of data communication. Data communications services are introduced that replace or supplement those in Phase 1, and data communications is the primary means of air-ground communication. Data communications supports increased automation in the aircraft and on the ground.

In developing the COCR, the following approach was adopted: First, using the overall context for future communications, a Phase 1 and a Phase 2 concept of operations was developed based on existing concepts for the evolution of ATM. Second, this concept of operations was used to identify ATS and AOC data communications services. Third, an operating environment in which these services would be provided was defined to ensure all implications of each service were addressed. Fourth, the services were grouped into eight categories; and security, safety, and performance assessments were performed for each of the eight categories. These assessments were used to specify high-level end-to-end requirements for each service/category. Next, an allocation of the high-level end-to-end requirements was made to the FRS. Using a method of operation for each service, indicative performance and capacity requirements were developed using a queuing model. This enabled capacity requirements that the FRS needs to support to be calculated. The COCR contains two example applications of the performance results.

There are a number of considerations to take into account when interpreting or employing these results:

- The communications loading analysis and capacity results represent the product of a set of assumptions and, while intended to be representative, should not be interpreted as the only method of determining the required throughput. This analysis is sensitive to a number of assumptions, and slight changes to any of several assumptions could alter the results.

- The analysis results are largely driven by the FRS allocations derived from service-based performance requirements. Should subsequent safety analyses change the service level hazard-based requirements, the FRS allocations may require revision, and the loading results could change.
- Implications of the operational concepts and services could impact communications loading. For example, sector sizes may grow beyond the sizes estimated herein, as the operational focus shifts from tactical control to strategic planning. Sector size growth may necessitate more dynamic sector boundaries and/or longer range communications. Any of these factors could impact these capacity results.

It should be noted that some of the values in this version of the COCR are considerably larger (up to 1600% in some cases) than those in version 1.0. This is due to a number of factors which include the following:

- Revision of the use of some services in domains
- Some corrections to the queuing model

However, the overall capacity results are broadly the same because the large increases in small values produce similar results.

This final version of the COCR has been developed primarily to estimate the requirements for a future communication system and to enable selection of supporting communications technologies. To achieve this, a requirements-driven approach was taken to assess air-ground and air-air data and voice ATS and AOC communications (i.e., safety and regularity of flight communications needed to support future ATM concepts). It is the result of many days of work from a dedicated team to capture future concepts and derive future communications requirements.

Several rounds of stakeholder consultations were conducted to ensure agreement on the process that was followed in completing the COCR. Wide distribution of earlier versions was provided via national and international forums. The technical requirements for an FRS were determined from the operational requirements, independent of any specific technology. This approach ensures that the communications requirements were based on needs, rather than being driven by technology. This document will be used within the EUROCONTROL/FAA FCS work to finalise the technology assessment, and it is offered to other activities as one method of identifying future communication requirements.

CHANGE SHEET

This is Version 2.0 of the COCR. Version 1.0 was circulated widely in March 2006, and the document has been reviewed by many Stakeholders. The input from those reviews, together with refinement of information by the COCR drafting team, has resulted in this new version. The main changes in this version compared with Version 1.0 include the following:

- Introduction of an Executive Summary
- Minor revision to the operational concepts taking into account the latest information from regional implementation planning
- Expansion in the definition of data link services – Section 2
- More comprehensive safety assessment; the itemized safety requirements for each service are contained in the Operational Services and Environment Definition reference document – Section 4
- Refinement of the performance requirements in light of the safety assessment – Section 5
- Modification to the queuing model used to produce the capacity requirements shown in Section 6
- Moving the example of real world use of the information to an appendix due to the availability of more comprehensive documents
- Correction of typographical errors

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ACRONYMS and ABBREVIATIONS

2-D	two dimensional (latitude and longitude)
3-D	three dimensional (latitude, longitude, and altitude)
4-D	four dimensional (latitude, longitude, altitude, and time)
ACAS	Aircraft Collision Avoidance System
ACL	ATC Clearance
ACM	ATC Communication Management
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
A-EXEC	Automatic Execution
AIRSEP	Air-to-Air Self-Separation
AMAN	Arrival Manager
AMC	ATC Microphone Check
AMN	Airspace Management and Navigation
ANSP	Air Navigation Service Provider
AOA	Autonomous Operations Area
AOC	Aeronautical Operational Control
AP	Action Plan
APT	Airport
ARMAND	Arrival Manager Information Delivery
A-SMGCS	Advanced-Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
ATSAW	Air Traffic Situation Awareness
ATSU	ATS Unit
AVS	Advisory Services
bps	bits per second
C&P	Crossing and Passing
C-ATSU	Controlling ATSU
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CFMU	Central Flow Management Unit
CIS	Clearance/Instruction Services
CMU	Communications Management Unit
CNS	Communication, Navigation and Surveillance
COCR	Communications Operating Concepts and Requirements
COS	class of service
COTRAC	Common Trajectory Coordination
CPDLC	Controller-Pilot Data Link Communication
CTOT	calculated take-off time
D-ALERT	Data Link Alert

D-ATIS	Data Link ATIS
D-ATSU	downstream ATSU
DCL	Departure Clearance
DCM	Data Communications Management Services
D-FLUP	Data Link Flight Update
DLL	Data Link Logon
D-ORIS	Data Link Operational En Route Information Service
D-OTIS	Data Link Operational Terminal Information Service
D-RVR	Data Link Runway Visual Range
DSC	Downstream Clearance
D-SIG	Data Link Surface Information and Guidance
D-SIGMET	Data Link Significant Meteorological Information
DSS	Delegated Separation Services
D-TAXI	Data Link Taxi Clearance
DYNAV	Dynamic Route Availability
E2E	end-to-end
ECAC	European Civil Aviation Conference
EFB	Electronic Flight Bag
EIS	Emergency Information Services
ENR	En Route
ETA	estimated time of arrival
ETD	estimated time of departure
EU	Europe
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration
FCI	Future Communications Infrastructure
FCS	Future Communications Study
FDPS	Flight Data Processing System
FIS	Flight Information Service
FL	Flight Level
FLIPCY	Flight Plan Consistency
FLIPINT	Flight Path Intent
FMS	Flight Management System
FPS	Flight Position/Intent/Preferences Services
FRS	Future Radio System
FUA	Flexible Use of Airspace
g	Gravity
GAT	General Air Traffic
GIS	Geographical Information System
HMI	Human Machine Interface
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ITP	In-Trail Procedure

JPDO	Joint Planning and Development Office
kbps	kilobits per second
KIAS	Knots Indicated Air Speed
KTAS	Knots True Airspeed
Kph	kilometres per hour
LDC	landing data calculation
M&S	Merging and Spacing
METAR	Meteorological Aerodrome Report
MHz	mega-Hertz
MIS	Miscellaneous Services
MLM	Mid-Level Model
MNPS	Minimum Navigation Performance Specification
m/s^2	metres per second squared
ms	milliseconds
MTCD	Medium Term Conflict Detection
N/A	Not available
NAS	National Airspace System (U.S.)
NextGen	Next Generation Air Transportation System
NGATS	Next Generation Air Transportation System
NM	nautical mile
NOTAM	Notice to Airmen
OAT	Operational Air Traffic
OOOI	Out-Off-On-In
OPA	Operational Performance Assessment
ORP	Oceanic, Remote, Polar
OSA	Operational Safety Assessment
OV	operational volume
PAIRAPP	Paired Approach
PIAC	Peak Instantaneous Aircraft Count
PIREP	Pilot Report
PPD	Pilot Preferences Downlink
PTT	Push to Talk
RCP	Required Communication Performance
RCTP	Required Communication Technical Performance
RF	radio frequency
RNAV	Area Navigation
RNP	Required Navigation Performance
rsvd	reserved
RTA	required time of arrival
RTD	required time of departure
RTCA	RTCA, Inc.
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minima

s	seconds
SAAM	System for Assignment and Analysis at a Macroscopic Level
SAP	System Access Parameters
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure
SPR	Safety and Performance Requirements
SSR	secondary surveillance radar
STAR	Standard Terminal Arrival Route
STATFOR	Statistics and Forecast
SURV	Air Traffic Control Surveillance
SV	service volume
TAF	Terminal Area Forecast
TD	Transit Delay
TFM	traffic flow management
TIS-B	Traffic Information Service – Broadcast
TMA	Terminal Manoeuvring Area
TOD	Top of Descent
TODC	takeoff data calculation
TV	transmission volume
UAS	Unmanned Aerial System
UCT	Undetected Corrupted Transaction
URCO	Urgent Contact
U.S.	United States
VDL	VHF Digital Link
VHF	very high frequency (108 – 137 MHz)
VTOL	vertical takeoff and landing

1 INTRODUCTION

1.1 Background

The European Organisation for the Safety of Air Navigation (EUROCONTROL) and the Federal Aviation Administration (FAA) have initiated a joint study under a Memorandum of Agreement through Action Plan 17 (AP 17) to identify potential future communications technologies to meet safety and regularity of flight communications requirements, i.e., those supporting Air Traffic Services (ATS) and safety related Aeronautical Operational Control (AOC) communications.

The Future Communications Study (FCS) has two main activities:

1. To identify the communication requirements to support emerging global future Air Traffic Management (ATM) concepts taking into account the needs of civil aviation and State aircraft operating as General Air Traffic (GAT) (i.e., Operational Air Traffic (OAT) is not considered).
2. To identify the most appropriate technology(ies) to meet these communication requirements.

This document covers the first activity by identifying the future concepts and defines resulting Communications Operating Concept and Requirements (COCR). The COCR will assist in the second activity by allowing key requirements to be matched against candidate technologies – existing or future. To achieve this goal the COCR identifies the requirements placed on the communications that take place through the aircraft and ground radios. These are collectively referred to as the Future Radio System (FRS). The COCR is technology-independent.

The operational requirements are drawn from ATM and AOC operating concepts expected to be implemented globally to achieve the required capacity, safety, and security. In particular, the International Civil Aviation Organisation (ICAO) Global ATM Operating Concept [1] and the International Air Transport Association (IATA) ATM Roadmap [9] were considered. Although not fully mature during the course of the study, concepts and requirements being defined in the Single European Sky ATM Research (SESAR) program and the United States (U.S.) Next Generation Air Transportation System (NextGen) programme were taken into account to the maximum extent possible with the information available.

The two primary drivers for the FRS are: 1) to provide an appropriate communication infrastructure to support future air traffic growth, and 2) to provide a consistent global solution to support the goal of a seamless air traffic management system.

The COCR considers two main phases of communications to support Air Traffic Management. The first phase (Phase 1) is based on existing or emerging data communication services. Initial steps of this phase are starting in some regions of the world now. The second phase (Phase 2) represents a new paradigm in the use of data communications. Phase 2 introduces new data communication services that replace or supplement those in Phase 1 as data communications become the standard method of air-ground communication and supports increased automation in the aircraft and on the ground. In Phase 2, the data communications system becomes integral to the provision of ATM. Figure 1-1 illustrates the expected timeframe of Phase 1 and Phase 2.

In Phase 1, voice communications capabilities remain central to the provision of ATM. In Phase 2, voice is only used for exceptional circumstances or for areas that do not require/have data communications implementation. In Phase 2, the ATM paradigm shifts from a tactical "Management by Intervention" to a strategic "Management by Planning and Intervention by Exception."

The FRS should, at a minimum, support the required air-ground and air-air data communications. The data communications may be broadcast, multicast, and/or addressed. Voice communication may be supported provided the FRS meets the voice requirements in the document.

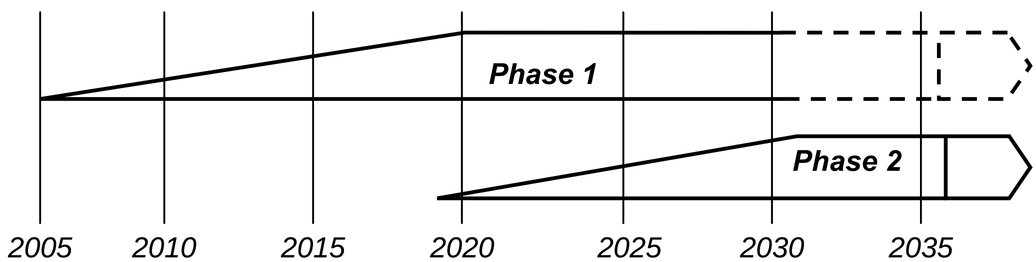

Figure 1-1: Phase 1 and Phase 2 Concept Evolution Over Time

In some regions of the world, Phase 1 data communications services are already being introduced through trials or implementation programmes. Other regions may begin Phase 1 implementation at any time, or not at all, based on their ATM needs. Similarly, the more advanced services described in Phase 2 may never be implemented in some regions for various reasons such as lower traffic density or lack of an adequate business case. This is depicted in Figure 1-1 by the dashed lines showing continued use of Phase 1 concepts in some regions while others have implemented those defined under Phase 2.

The performance requirements provided in this document are a "snapshot" of what demands a full set of Phase 1 services anticipated to be in place in some regions around 2020 would place on the communications system. The performance requirements for Phase 2 represent the same for a fully matured set of services anticipated to be in place in some regions in the 2030 timeframe.

A particular aircraft or ground system is not required to implement any of the services contained in this document. Coordination between the regional stakeholders will determine the operational services that benefit the local environment as part of a global infrastructure.

1.2 Scope

The scope of the COCR document is to identify concepts, requirements, and trends that will be the basis for selecting the FRS. Air Navigation Service Providers (ANSPs) and industry are in the formative stages of determining many of the underlying future concepts considered in this document. While not meant to be a complete representation of the future global airspace operating concepts, this document provides useful input in the ongoing effort to define them.

Civil-military interoperability has also been addressed in the development of the COCR through coordination with the relevant military representatives. This helped refine requirements in the areas of integrity, reliability, and security. Regulatory aspects for civil or military ATM systems are not considered in this document.

The aviation community is considering the requirements for operating Unmanned Aerial Systems (UASs) within the ATM infrastructure. Studies considering the implications of operating UASs in non-segregated airspace are underway in several regions of the world. Due to their immaturity, requirements to support command and control links (i.e., telecommand and telemetry) have not been addressed in the COCR. When UAS requirements in this area become available, the command and control link traffic load could be estimated. All other communications services with UASs are considered to be the same as those with manned aircraft, i.e., UAS operation is transparent for the ATM system. In the future, in some parts of the world, the number of these vehicles may represent a large portion of an Air Traffic Service Unit's (ATSU's) traffic load. When providing ATS to a UAS, this may involve the relay of communication and execution instructions to and from a remote pilot; however, operational performance requirements between an ATSU and an UAS remain the same as those between an ATSU and any manned aircraft.

Information security requirements associated with the ATS and AOC services defined in Section 2 are discussed in Section 4.3. A number of new security services that monitor and control the physical security of aircraft and the air traffic system are currently under consideration. These services include provision of real-time video transmission from the cockpit and provision of direct communications between aircraft and security organisations. These physical security services are still being defined, and it is not clear whether the FRS, a passenger communications system, or a new dedicated communications system would be used to provide them. Therefore, the physical security services are not discussed further in this document.

1.3 Context

The ATM environment in the timeframe of the FCS will continue to consist of ground Human Machine Interfaces (HMIs), voice switches, Flight Data Processing Systems (FDPSs) – (the Automation System), ground communications systems, routers, networks, radio ground stations, airborne radios, and communication end systems (e.g., airborne Communications Management Units [CMUs] and ground data communications application processors). These components, combined in an end-to-end chain must meet the performance and safety requirements for voice and data applications.

In this document, the term FRS[1] is used to refer to the physical implementation of the radio components of a communication system that meets these requirements. The scope of the FRS is illustrated in Figure 1-2. The FRS is part of the overall Future Communications Infrastructure (FCI), which includes all the components (e.g.,

[1] A singular reference to technology is used, but the FRS may be a combination of technologies.

processors, applications, and networks) needed for the ANSP, AOC, and aircraft to communicate with each other.

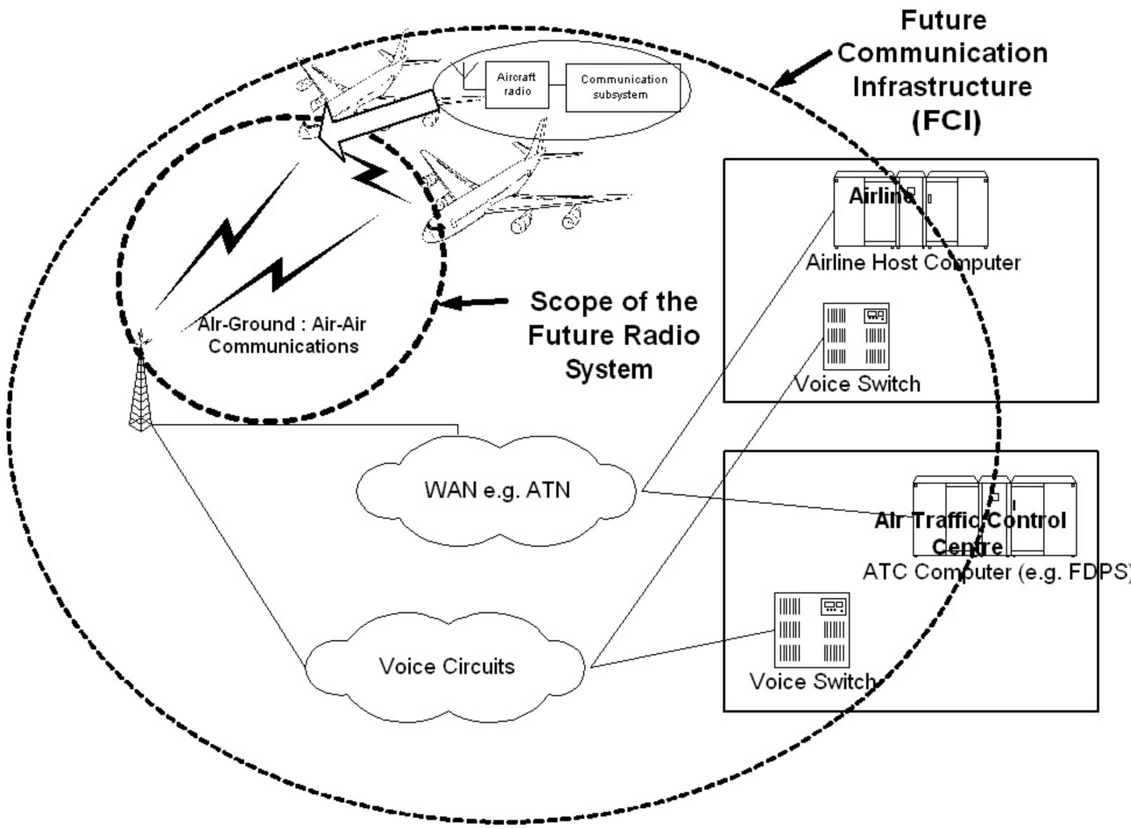

Figure 1-2: Scope of the Future Radio System (FRS) as part of the FCI

1.4 Approach

To determine the overall context for future communications, numerous concepts of operations, vision statements, and plans being developed and circulated by ANSPs around the world were reviewed. These are identified in the document reference list in Section 1.6.

The following steps describe the approach adopted in producing the communication operating concepts and requirements for the FRS.

1. Develop notional vision and universal operating concepts for air traffic management.
2. Identify and define the ATS and AOC required services.
3. Define the operating environment, in which these services would be provided, to ensure all implications of each service were addressed.
4. Perform safety, information security, and performance assessments for the air traffic services.

5. Establish high-level requirements that each service would have to meet (so that the specified outcome or benefit of the service could be achieved safely and efficiently), and allocate requirements to the FRS.
6. Calculate the FRS voice and data capacity required to deliver the specified air traffic services.
7. Put the COCR into perspective and facilitate future use of the COCR by applying the results to sample applications.

1.5 Document Organisation

This document is organised as follows:

- **Section 1 (Introduction):** This section includes background and document scope and organization.
- **Section 2 (Operational Services):** This section describes the operational services that are referenced in the Section 3 scenarios.
- **Section 3 (Operational Concept, Environment, and Scenarios for Communications):** This section discusses operational trends and presents real world "day-in-the-life-of" scenarios to describe the operational concepts.
- **Section 4 (Operational, Safety, and Security Requirements):** This section provides high-level safety and security communications requirements.
- **Section 5 (Performance Requirements):** This section provides performance requirements.
- **Section 6 (Communication Loading Analyses):** This section presents a detailed communication system loading analysis based on an estimation of message sizes, message frequencies, performance requirements, and airspace aircraft densities.
- **Section 7 (Conclusions):** This section provides the document conclusions.

An *Acronym and Abbreviation* section is provided at the beginning of the document.

1.6 Document References

A complete reference list is shown in Appendix F. Document reference numbers appear in the COCR as "[x]."

2 OPERATIONAL SERVICES

2.1 Introduction

This section describes the Air Traffic Services (ATS) and Aeronautical Operational Control (AOC) services that are expected during Phase 1 and Phase 2. Section 3 divides the transition/evolution process of these services into Phases 1 and 2 and provides scenarios demonstrating how the services in each phase could be used.

The focus and definition of the following services is data communications. In Phase 1, voice communications will continue to support most of these services in continental environments when required by the time criticality of the exchange. In Phase 2, data communications will become the primary means of communication, with voice being retained for non-routine situations.

2.2 Air Traffic Services

The ATS data communications services vary by the domain in which the aircraft is or will be operating. The COCR divides airspace into five representative airspace domains. Although specific regional differences exist, Table 2-1 contains the airspace domain definitions used in this document.

Domain	COCR Definition
Airport (APT)	The APT domain consists of an area 10 miles in diameter and up to ~5000 ft consisting of the airport surface and immediate vicinity of the airport.
Terminal Manoeuvring Area (TMA)	The TMA domain consists of the airspace surrounding an airport, typically starting at ~5000 ft up to ~FL245, that is the transition airspace used by Air Traffic Control (ATC) to merge and space aircraft for landing or for entrance into the Enroute domain. The TMA domain typically radiates out ~50 nautical miles (NM) from the centre of an airport. The COCR assumes that the airspace used in departure and arrival phases of flight are identical except for the direction of flight.
En Route (ENR)	The ENR domain consists of the airspace that surrounds the TMA domain starting at ~FL245 to ~FL600 and is the continental or domestic airspace used by ATC for the cruise portion of the flight. It also includes areas to the lower limits of controlled airspace (e.g., 1,500 feet) where an airport or TMA does not exist. At the ATSU level, the COCR assumes this domain to have a horizontal limit extending 300 NM by 500 NM.
Oceanic, Remote, Polar (ORP)	The ORP domain is the same as the ENR domain, except that it is associated with geographical areas generally outside of domestic airspace. The COCR assumes this domain to have a horizontal limit extending 1000 NM by 2000 NM.
Autonomous Operations Area (AOA)	The AOA domain is a defined block of airspace which is associated with autonomous operations where aircraft self-separate (i.e., Air Traffic Control is not used). The defined block may change vertical or horizontal limits or usage times based on, among other factors, traffic densities. The COCR assumes this domain to have horizontal limits of 400 NM by 800 NM.

Table 2-1: Airspace Domain Definitions

ATS services are expected to be utilised in the respective domains or in the AOA buffer zone, but not within the AOA domain itself. Many ATS communications can be done using voice or data. The services in the following list are considered to be either not supportable by voice (e.g., Automatic Execution [A-EXEC]) or may be operationally inefficient when implemented by voice. Some services can be supported by voice broadcast (e.g., Automatic Terminal Information Service [ATIS]); however, a data communications implementation could reduce Flight Crew workload and allow them to receive remote reports.

1. Air Traffic Control (ATC) Microphone Check (AMC)
2. Air Traffic Control Surveillance (SURV)
3. Automatic Execution (A-EXEC)
4. Common Trajectory Coordination (COTRAC)
5. Data Link Alert (D-ALERT)
6. Data Link Automatic Terminal Information Service (D-ATIS)
7. Data Link Logon (DLL)
8. Data Link Operational Route Information Service (D-ORIS)
9. Data Link Operational Terminal Information Service (D-OTIS)
10. Data Link Runway Visual Range (D-RVR)
11. Data Link Significant Meteorological Information (D-SIGMET)
12. Data Link Surface Information and Guidance (D-SIG)
13. Data Link Flight Update (D-FLUP)
14. Dynamic Route Availability (DYNAV)
15. Flight Plan Consistency (FLIPCY)
16. Flight Path Intent (FLIPINT)
17. System Access Parameters (SAP)
18. Traffic Information Service – Broadcast (TIS-B)
19. Urgent Contact (URCO)
20. Wake Vortex (WAKE)
21. Air-to-Air Self Separation (AIRSEP)

2.2.1 ATS Voice Services

Most of the current air-ground and air-air voice communications functions will continue to be needed. Voice communications have some advantages over data communications, such as: high availability, low end-to-end latencies, the ability to convey human feelings, flexibility of dialogue, provision of a party-line, and use for non-routine, time critical, or emergency situations. This does not apply to UAS operations or direct automation-to-automation operations in Phase 2. The party-line will continue to be required to support broadcast of Flight Crew intent, e.g., traffic arriving and departing at uncontrolled airports.

Although some services, such as Data Link Taxi Clearance (D-TAXI), are specifically data communications services, taxi clearances will continue to be provided by voice for non-equipped aircraft. In addition, a ground-to-air broadcast voice will continue to be used to support dissemination of Flight Information Service (FIS) information. The need for this voice broadcast service could be diminished over time depending on the extent of data communications equipage.

2.2.2 ATS Data Services

The ATS data services have been grouped into eight categories as indicated in Table 2-2.

Data Communications Management Services (DCM)	**Clearance/ Instruction Services (CIS)**	**Flight Information Services (FIS)**	**Advisory Services (AVS)**	**Flight Position/ Intent/ Preferences Services (FPS)**	**Emergency Information Services (EIS)**	**Delegated-Separation Services (DSS)**	**Miscellaneous Services (MIS)**
Data Link Logon (DLL) ATC Communication Management (ACM)	ATC Clearance (ACL) Departure Clearance (DCL) Downstream Clearance (DSC) ATC Microphone Check (AMC) Data Link Taxi (D-TAXI) Common Trajectory Coordination (COTRAC)	Data Link Automatic Terminal Information Service (D-ATIS) Data Link Operational Terminal Information Service (D-OTIS) Data Link Operational En Route Information Service (D-ORIS) Data Link Significant Meteorological Information (D-SIGMET) Data Link Runway Visual Range (D-RVR) Data Link Surface Information and Guidance (D-SIG)	Arrival Manager Information Delivery (ARMAND) Dynamic Route Availability (DYNAV) Data Link Flight Update (D-FLUP)	Surveillance (SURV) Flight Plan Consistency (FLIPCY) Flight Path Intent (FLIPINT) System Access Parameters (SAP) Wake Broadcast (WAKE) Pilot Preferences Downlink (PPD) Traffic Information Service-Broadcast (TIS-B)	Data Link Alert (D-ALERT) Urgent Contact (URCO)	In-Trail Procedures (ITP) Merging and Spacing (M&S) Crossing and Passing (C&P) Paired Approach (PAIRAPP)	Air-to-Air Self Separation (AIRSEP) Auto Execute (A-EXEC)

Table 2-2: COCR ATS Service Groups

2.2.2.1 Data Communications Management Services

2.2.2.1.1 Data Link Logon (DLL)

The DLL service exchanges information between an aircraft and an ATSU to support other addressed data communications services. The DLL service is executed prior to any other addressed data communications service. It is used to uniquely identify an aircraft and to provide version and address information for all data communications services. Once initiated, DLL provides the flight identification to the avionics, and the remainder of the DLL takes place automatically without Flight Crew involvement.

The DLL information must be available for each ATSU that will offer data communications services. The DLL initiation only needs to be completed once for a given flight. For this nominal case, the ATSU with which the initiation function was conducted does one of the following:

- Provides all other required ATSUs information in the DLL initiation response.
- Allows other ATSUs to access the DLL initiation information (e.g., DLL server).
- Provides aircraft DLL initiation information to a subsequent ATSU, and each subsequent ATSU again passes the DLL initiation information to its subsequent ATSU.

Alternatively, the DLL service can be accomplished by initiation of the DLL service by the Flight Crew separately for each ATSU, e.g., when ground-ground communication is not provided to transfer DLL information among ATSUs.

The DLL service consists of the following types of exchanges:

- **Initiation (I):** The initial means to exchange application information between an aircraft and ATSU, and to provide flight data to an ATSU. This function is between a given aircraft-ATSU pair, but when available, information for other ATSUs may be exchanged.
- **Contact (C):** An ATSU provides the DLL address of a specified ATSU to an aircraft and requests the initiation function be performed between the aircraft and the specified ATSU. The specified ATSU is different from the ATSU requesting the contact.

The DLL service uses addressed communications.

2.2.2.1.2 ATC Communication Management (ACM)

The ACM service is used for the following:

- To manage the transfer of data communication authority between sectors and/or ATSUs
- To terminate data communications with an ATSU
- To issue a change of voice frequency

When the ACM service is used for transfers between ATSUs/sectors or a change of frequency, it is initiated by one of the following:

- The transferring sector or ATSU
- A request from the receiving sector or ATSU
- A request from the Flight Crew

The ACM service consists of the following types of exchanges:

- Requests to initiate and terminate air-ground control communications
- Indication of the next data authority
- Voice frequency contact and monitor messages

The ACM service uses addressed communications.

2.2.2.2 Clearance/Instruction Services

The following subsections provide a definition of the ATS Clearance/Instruction data communications services.

Note: Although the some ATS clearance/instruction data communications services may be generated by a ground automation system and sent directly to an aircraft without Controller review/action, the execution of any trajectory altering messages will continue to require Flight Crew action prior to execution by on-board automation/avionics.

2.2.2.2.1 ATC Clearance (ACL)

A Flight Crew under the control of an ATSU transmits reports; makes requests; and receives clearances, instructions, and notifications using ACL. The ACL service specifies dialogue exchanges via air-ground addressed communications between Flight Crews and Controllers working the specific position/sector associated with the aircraft's physical location. The ACL service may be initiated by either the ground automation/Controller or the avionics/Flight Crew. Some ACL exchanges, (e.g., altimeter settings and secondary surveillance radar [SSR] transponder code assignments) can be transmitted without Controller review/action. ACL is available in all flight phases (except in the AOA domain beyond the buffer zone).

The ACL service consists of the following types of exchanges:

- ATC clearances, instructions, notifications, and requests
- Flight crew requests, reports, notifications, and compliance indications

The ACL service uses addressed communications.

2.2.2.2.2 Departure Clearance (DCL)

A flight due to depart from an airfield must obtain a departure clearance from the Controlling ATSU (C-ATSU). The DCL service enables a Flight Crew to receive their departure clearance and related route-of-flight information by data communications. The DCL service provides automated assistance to Controllers and Flight Crews to perform these communication exchanges.

DCL clearances are usually provided in response to a Flight Crew data communications request, but may also be initiated by the Controller/ATSU automation. A DCL clearance requires a response from the Flight Crew. The DCL service consists of a DCL request(s) from the Flight Crew and DCL clearances and revisions, as required, from the Controller or ATSU automation. DCL is available prior to takeoff. The DCL service consists of the following types of exchanges:

- ATC departure clearances and revisions
- Flight crew clearance requests and compliance indications

The DCL service uses addressed communications.

2.2.2.2.3 Downstream Clearance (DSC)

A Flight Crew may need to obtain clearances or information from an ATSU not yet in control of the aircraft but that will be responsible for control of the aircraft later during the flight, i.e., a downstream ATSU (D-ATSU).

The DSC service can only be initiated by a Flight Crew request for a DSC. The DSC service consists of a DSC request(s) from the Flight Crew and DSC clearances and revisions, as required, from the Controller or ATSU automation. A DSC clearance requires a response from the Flight Crew.

Clearances or information received through downstream communications that have an affect on the aircraft's trajectory prior to the D-ATSU's airspace are explicitly coordinated with the C-ATSU.

An aircraft may be in any phase of flight when requesting and obtaining a downstream clearance. The Flight Crew conducts DSC with only one D-ATSU at a time.

In Phase 2 this service is largely superseded by COTRAC.

The DSC service consists of the following types of exchanges:

- Flight crew requests, reports, notifications, and compliance indications
- ATC downstream clearances, instructions, and requests

The DSC service uses addressed communications.

2.2.2.2.4 ATC Microphone Check (AMC)

When the voice channel is blocked, such as when an aircraft has a stuck microphone, the AMC service is used to contact some or all aircraft under control of that sector/position. The AMC message instructs a Flight Crew to check the aircraft's communication equipment to determine if the cause of the problem is a stuck microphone on their aircraft and, when required, take corrective action.

The AMC service consists of the following type of exchange:

- Uplink of instruction to check for a stuck microphone

The AMC service may use addressed or broadcast communications.

2.2.2.2.5 Data Link Taxi Clearance (D-TAXI)

The Flight Crew of an aircraft preparing to depart from an airport or of an aircraft that has just landed must obtain a series of clearances from the C-ATSU in order to proceed from a gate/stand to the runway or from the runway to a gate/stand. The D-TAXI service provides automated assistance to Controllers and Flight Crews to perform these communication exchanges for ground-movement operations. D-TAXI clearances are usually provided in response to a Flight Crew request but may also be initiated by the Controller/ATSU automation. D-TAXI clearances may be amended. D-TAXI clearances require a response from the Flight Crew.

In general, for arriving aircraft, a D-TAXI clearance may be requested and/or issued once the aircraft lands. In some cases, in order to improve surface management, D-TAXI instructions for arriving aircraft may be issued to a Flight Crew while the aircraft is in the approach pattern. Then, when the landing uses the anticipated turn-off, the previously issued D-TAXI can be confirmed for execution.

The D-TAXI service consists of the following types of exchanges:

- ATC taxi clearances, instructions, and requests
- Flight crew requests, reports, notifications, and compliance indications

The D-TAXI service uses addressed communications.

2.2.2.2.6 Common Trajectory Coordination (COTRAC)

The COTRAC service is used to establish and coordinate trajectory agreements in real-time using graphical interfaces and automation systems, in particular the Flight Management System (FMS). COTRAC provides trajectory agreements involving multiple constraints, e.g., latitude/longitude, altitude, and airspeed.

Initially, COTRAC may be restricted to the use of two-dimensional (2-D) trajectories consisting of, for example, departure point, top-of-climb, top-of-descent, and arrival fix crossing constraints. As air and ground system capabilities improve, COTRAC will be capable of providing four-dimensional (4-D) trajectories.

The COTRAC service may be initiated by either the Flight Crew or the controller/ATSU. Although not part of the air-ground COTRAC data communications exchange, 4-D trajectory-based flight plans may be coordinated through the use of COTRAC.

A Controller/C-ATSU automation may initiate COTRAC by issuing either a COTRAC trajectory clearance message or a trajectory constraints message. A COTRAC trajectory is simply a clearance and is handled as such. A trajectory constraint message provides the Flight Crew a set of constraints (e.g., required time of arrivals [RTAs], 4-D waypoints) that must be taken into account when requesting a trajectory. The Flight Crew can then respond with a trajectory request, which may be in turn responded to with a trajectory clearance.

A Flight Crew can initiate COTRAC by requesting a specific COTRAC trajectory. The Controller/C-ATSU automation then responds with 1) a requested COTRAC trajectory clearance, or 2) a set of constraints used to negotiate an alternate COTRAC trajectory, or 3) an indication that a COTRAC trajectory cannot be provided.

The COTRAC service consists of the following types of exchanges:

- **Trajectory Constraints:** A set of constraints provided to a Flight Crew (e.g., RTAs and trajectory points).
- **Trajectory Request:** A Flight Crew request that includes a series of trajectory points including RTAs taking into account any supplied constraints.
- **Trajectory Clearance:** A clearance that includes a series of trajectory points, including RTAs.
- **Trajectory Non-conformance:** A report from the Flight Crew or aircraft automation indicating non-conformance with the trajectory clearance.

Note: FLIPINT or SURV may be used instead of a Trajectory Non-conformance indication, to provide aircraft position and intent data either periodically or in response to a ground specified non-conformance event.

Prior to initiating the COTRAC service, a trajectory-based flight plan may be filed. This flight plan may include a series of 2-, 3-, or 4-D trajectory points, including key points (e.g., top-of-descent), ATS route designators or fix names, estimated times of arrival (ETAs), required times of arrival (RTAs) (as needed), required time of departure (RTD) (if needed), and additional information such as Communication, Navigation and Surveillance (CNS) performance characteristics (e.g., Required Navigation Performance [RNP]-4, Required Communication Performance [RCP]-120), tolerance of time variability from the proposed departure, and priority ranking relative to other flights proposed by that user. The times at the points along the trajectory, as desired and predicted by the user, are referred to as ETAs. The trajectory-based flight plan is the filed flight plan that will later be negotiated prior to flight and is a ground-ground communication.

The COTRAC service uses addressed communications.

2.2.2.3 Flight Information Services

2.2.2.3.1 Data Link Automatic Terminal Information Service (D-ATIS)

D-ATIS provides automated assistance in requesting and delivering air traffic information including: meteorological conditions, operating procedures, runways and approaches in use, and various other information which may affect the departure, approach, and landing flight phases as well as surface operations relevant to a specified airport(s) in any phase of flight (except in the AOA domain outside of the buffer zone).

ATIS information is updated upon the issuance of a new weather report or when conditions or procedures affecting various components of the ATIS message change by specified criteria.

D-ATIS supplements and/or replaces the ATIS available as a voice broadcast service provided at aerodromes worldwide. All types of ATIS provided by voice are also provided by data (i.e., arrival, departure and combined).

D-ATIS does not change the operational requirement to obtain ATIS prior to contacting the associated ATS facility but does replace the repetition of the ATIS designator back to the Controller with transmission of the ATIS code in a data communications message to the Controller/ATSU.

When ATIS is provided by both voice and data, the operational content of voice and data ATIS must be semantically identical and updated simultaneously.

D-ATIS consists of the following types of exchanges:

- Downlink of request (i.e., demand, periodic or event contract) for ATIS reports
- Uplink of contract acknowledgements
- Uplink of arrival, departure, or combined ATIS reports

D-ATIS can use addressed and/or broadcast communications.

Note: The D-ATIS information may be included as part of the information provided by D-OTIS.

2.2.2.3.2 Data Link Operational Terminal Information Service (D-OTIS)

D-OTIS provides Flight Crews with compiled meteorological and operational flight information derived from ATC, ATIS, Meteorological Aerodrome Report (METAR), Notice to Airmen (NOTAM), and Pilot Report (PIREP) information tailored to the departure, approach and landing phases of flight.

The D-OTIS information is updated when the ATIS, METAR, NOTAM, or PIREP components of the OTIS message change by specified criteria or delivery of operational information (e.g., delays, Collaborative Decision Making (CDM) sequences), is considered necessary by ATC.

D-OTIS consists of the following types of exchanges:

- Downlink of request (i.e., demand, periodic, or event contract) for OTIS reports
- Uplink of contract acknowledgements
- Uplink of OTIS reports

D-OTIS can use addressed and/or broadcast communications.

2.2.2.3.3 Data Link Operational En Route Information Service (D-ORIS)

D-ORIS provides Flight Crews with compiled meteorological and operational flight information, derived from ATC, En Route weather information, NOTAMs, and other sources, specifically relevant to an area to be over-flown by the aircraft.

The D-ORIS information is updated when the specified components of the D-ORIS message change by specified criteria or delivery of operational information (e.g., delays and CDM sequences), is considered necessary by ATC.

D-OTIS consists of the following types of exchanges:

- Downlink of request (i.e., demand, periodic, or event contract) for ORIS reports
- Uplink of contract acknowledgements
- Uplink of ORIS reports

D-ORIS can use addressed and/or broadcast communications.

2.2.2.3.4 Data Link Significant Meteorological Information (D-SIGMET)

The D-SIGMET service provides Flight Crews with advisories of the occurrence, or expected occurrence, of weather phenomena that may affect the safety of aircraft operations. The preparation and issue of SIGMET reports is the prime responsibility of meteorological watch offices. SIGMET information messages are distributed on ground initiative to aircraft in flight through associated ATSUs.

The D-SIGMET service consists of the following types of exchanges:

- Uplink of SIGMET reports

The D-SIGMET service can use addressed and/or broadcast communications and is provided on an event basis only.

Note: D-SIGMET information may also be embedded in the D-ATIS, D-OTIS or D-ORIS report when applicable.

2.2.2.3.5 Data Link Runway Visual Range (D-RVR)

The D-RVR service provides Flight Crews with up-to-date RVR information related to an airport's runway(s). Flight Crews can request RVR information related to any airport's runway(s) during any phase of flight. The D-RVR information is updated when the specified components of the D-RVR message change by specified criteria.

The D-RVR service consists of the following types of exchanges:

- Downlink of request (i.e., demand, periodic, or event contract) for RVR information
- Uplink of contract acknowledgements
- Uplink of RVR information

The D-RVR service can use addressed and/or broadcast communications.

2.2.2.3.6 Data Link Surface Information and Guidance (D-SIG)

D-SIG provides current airport elements necessary for ground movements (e.g., taxiway closures, runway re-surfacing) to the Flight Crew.

D-SIG is initiated by the ground automation upon completion of the DCL for departures or upon recognition of transition to initial approach for arrivals.

In Phase 1, not many aircraft avionics will have advanced to the stage of implementing a moving map where the D-TAXI instruction would be overlaid on the D-SIG. Therefore, the D-SIG information in Phase 1 is used for situational awareness only.

In Phase 2, the integration of the displays has occurred and the D-SIG information is overlaid on on-board airport map displays that show significant surface information including the D-TAXI route.

The D-SIG service consists of the following types of exchanges:

- Uplink of airport data which may be displayed on-board

The D-SIG service can use addressed and/or broadcast communications.

2.2.2.4 Advisory Services

2.2.2.4.1 Arrival Manager (AMAN) Information Delivery (ARMAND)

The ARMAND service transmits relevant advisories directly from the ground automation to Flight Crews that are within the optimum-planning horizon of the AMAN.

The ARMAND service transmits target, expected, or revised controlled arrival time advisories relevant to the destination airport or points in space along the aircraft's route. The ARMAND service only offers advisories, not clearances, and thus is consistent with the principle of not modifying the route of an aircraft that is in another sector's airspace. The aircraft may be beyond the limits of the ATSU that contains the restriction point when the ARMAND service is initiated.

To enforce the AMAN time, a subsequent ACL instruction to cross a significant point at a specified time and/or speed and/or level is issued.

The ARMAND service consists of the following types of exchanges:

- Uplink of controlled arrival times

The ARMAND service uses addressed communications.

Note: COTRAC is expected to supersede ARMAND for COTRAC-equipped aircraft.

2.2.2.4.2 Dynamic Route Availability (DYNAV)

The DYNAV service is used by an ATSU to offer a Flight Crew alternative routes as they become available during the course of a flight. DYNAV may be initiated automatically by the automation or manually by the Controller. The ATSU does not need to be in control of the aircraft when providing the DYNAV service.

The following situations may result in availability of alternative routes: lifting of military Special-Use Airspace reservations or initiation or dissipation of weather phenomena or other operational restrictions.

The Flight Crew may request a clearance to use a DYNAV-offered route via the ACL, DSC, or COTRAC service.

Note: Clearances used to provide a route offered by the DYNAV service, like any clearance, are issued once the aircraft is under the control of the ATSU responsible for the DYNAV route or by a D-ATSU when coordinated with any affected ATSU(s) between the aircraft's current position and the D-ATSU airspace.

The DYNAV service consists of the following types of exchanges:

- Uplink of available alternative route(s)

The DYNAV service uses addressed communications.

2.2.2.4.3 Data Link Flight Update (D-FLUP)

The D-FLUP service provides ATM-related operational data and information to optimise flight operations. Examples of D-FLUP data include flight-specific information related to the departure sequence, slot-time allocations, flow management advisories, airspace/airport configurations, and special operations such as de-icing. D-FLUP operates on a demand, periodic, or event basis and is available in any phase of flight.

The D-FLUP service consists of the following types of exchanges:

- Request for D-FLUP
- Uplink of ATM operational data

The D-FLUP service may use addressed and/or broadcast communications.

2.2.2.5 Flight Position, Flight Intent, and Flight Preferences Services

2.2.2.5.1 Air Traffic Control Surveillance (SURV)

The SURV service uses Automatic Dependent Surveillance (ADS) positional information provided by equipped aircraft for separation or monitoring purposes. The information can be provided via broadcast, (i.e., ADS – Broadcast [ADS-B]), or via addressed contracts, (i.e., ADS – Contract [ADS-C]). This service can be conducted in all domains independent of radar support.

When SURV uses ADS-B, the aircraft providing the data must have the capability to broadcast out, and the recipient for the ADS data (either another aircraft or a ground system) must have the capability to receive and process ADS-B reports.

When SURV uses ADS-C, the aircraft providing the data must have the capability to respond to contract requests for ADS-C data, and the requester for/recipient of the ADS data (either another aircraft or a ground system) must have the capability to establish ADS contracts (demand, periodic, and/or event) and receive and process ADS-C reports.

The SURV service consists of the following types of exchanges:

- Uplink of contract(s) requesting ADS-C data
- Downlink of contract acknowledgements
- Downlink of current and predicted position, meteorological data, other flight data (i.e., ADS-C reports)
- Aircraft broadcast of position data (i.e., ADS-B reports)

The SURV service uses addressed and/or broadcast communications.

Note: The SURV service supports the surveillance portion of the Delegated Separation Services (i.e., the ITP, M&S, C&P, and PAIRAPP).

2.2.2.5.2 Flight Plan Consistency (FLIPCY)

The FLIPCY service provides information to an ATSU for the detection of inconsistencies between the ATC flight plan and the flight plan activated in the aircraft's Flight Management System (FMS).

FLIPCY consists of a ground-initiated request (manual or automated) for route information from the aircraft. The request can be specified as a period of time or as a number of waypoints (e.g., 15 minutes or 6 waypoints) relative to the aircraft's current position. The aircraft responds with the route data it can supply based on the request. This service is conducted without Flight Crew involvement.

The FLIPCY service can be initiated prior to entry into an ATSU's airspace, after issuance of a departure clearance, or at any time an ATSU requires such information.

This information may result in an ACL instruction to resolve any inconsistency between the aircraft's reported route of flight and the ATSU's stored route of flight for that aircraft.

The FLIPCY service consists of the following types of exchanges:

- Uplink of contract(s) requesting FLIPCY data
- Downlink of contract acknowledgements
- Downlink of current and predicted position, meteorological data, and ground speed

The FLIPCY service uses addressed communications.

2.2.2.5.3 Flight Path Intent (FLIPINT)

The FLIPINT service provides information to an ATSU for the detection of inconsistencies between the ATC flight plan and the flight plan activated in the aircraft's FMS.

The FLIPINT service is established automatically by an ATSU or manually by a Controller. FLIPINT data is downlinked on demand, periodically, or upon occurrence of an event, and will include the position (latitude, longitude, and altitude), ground speed, meteorological information, and up to 128 subsequent waypoints with time, altitude, and speed projections as requested. The aircraft responds with the route data it can supply based on the request. This service is conducted without Flight Crew involvement. The type or amount of data (e.g., report criteria and/or report contents) requested via FLIPINT may be modified by the ATSU/Controller each time a FLIPINT request is issued.

The FLIPINT service can be initiated prior to entry into an ATSU's airspace, after issuance of a departure clearance, to monitor compliance with a COTRAC trajectory clearance, or at any time an ATSU requires such information.

The FLIPINT service consists of the following types of exchanges:

- Uplink of contract(s) requesting FLIPINT data
- Downlink of contract acknowledgements
- Downlink of current and predicted position, meteorological data, and ground speed

The FLIPINT service uses addressed communications.

Note: The FLIPINT service may provide the conformance monitoring required in the COTRAC service. FLIPINT information may result in ACL or COTRAC instructions to resolve any inconsistency between the aircraft's reported route of flight and the ATSU's stored route of flight for that aircraft.

FLIPINT data can be used to perform the FLIPCY service, superseding the necessity to implement FLIPCY.

2.2.2.5.4 System Access Parameters (SAP)

The SAP service consists of the extraction, transmission, and provision to the Controller or ground automation of specific airborne avionics tactical flight information (e.g., indicated heading, indicated air speed or mach, vertical rate, selected level, and wind vector). The ground system uses the SAP service to provide enhancements to ATC surveillance and trajectory prediction functions. The SAP service is initiated by ATSU automation and conducted on a periodic or event driven basis.

SAP is primarily used in En Route and terminal areas, but is available in all phases of flight.

The SAP service consists of the following types of exchanges:

- Uplink of contract(s) requesting SAP data
- Downlink of contract acknowledgement(s)
- Downlink of indicated heading, indicated air speed or mach, vertical rate, selected level, and wind vector

The SAP service uses addressed communications.

2.2.2.5.5 Wake Service (WAKE)

The WAKE service provides information enabling encounter-specific separation based on wake vortex characteristics. Ground automation uses the WAKE parameters (e.g., aircraft type, weight, and flap and speed settings) and other environmental data to determine the required minimum separation between a pair of aircraft to avoid a wake vortex encounter. The WAKE service is available in all domains except ORP and AOA.

The WAKE service consists of the following types of exchanges:

- Broadcast of WAKE characteristics (e.g., aircraft type, weight, and flap and speed settings)

The WAKE service uses broadcast communications.

2.2.2.5.6 Pilot Preferences Downlink (PPD)

The PPD service provides automated support for ground automation/Controller trajectory and traffic flow planning. It is used by a Flight Crew to express flight preferences or limitations. The PPD service allows the Flight Crew, in all phases of a flight, to provide the ground automation/Controller with a set of preferences beyond what is available in the filed flight plan (e.g., maximum acceptable flight level) and request modification of some flight plan elements (e.g., desired route or speed limitations).

The PPD service data is either transmitted by the Flight Crew to the ATSU each time they enter/update the information, or it can be transmitted in response to a ground automation/Controller request. PPD may be used prior to an aircraft being under control of the sector to which the information pertains. PPD information is passed to the next ATSU as part of ground-ground coordination when the information is still pertinent.

The PPD service consists of the following types of exchanges:

- Uplink of request for PPD data
- Downlink of flight limitations (e.g., maximum acceptable flight level)
- Downlink of pilot flight preferences
- Downlink of flight plan modification requests (e.g., desired route or speed limitations)

The PPD service uses addressed communications.

2.2.2.5.7 Traffic Information Service Broadcast (TIS-B)

The TIS-B service is used by a ground system to broadcast sensor-based traffic information and/or re-broadcast received air-ground ADS-B information. TIS-B information is displayed on aircraft avionics to provide the Flight Crew with situational awareness of proximate traffic.

The TIS-B service consists of the following types of exchanges:

- Uplink broadcast of flight traffic positional information

The TIS-B service uses ground broadcast communications.

Note: The TIS-B service will be implemented for some classes of users in various domains.

TIS-B will become unnecessary in Phase 2 when all aircraft are equipped with the same ADS-B technology.

2.2.2.6 Emergency Information Services

2.2.2.6.1 Data Link Alert (D-ALERT)

The D-ALERT service enables a Flight Crew to notify appropriate ground authorities when the aircraft is in a state of emergency or in an abnormal situation.

The D-ALERT information is sent to the C-ATSU who determines which authorities (e.g., fire/rescue, police, AOC) should receive the details of the message. Appropriately-equipped aircraft may distribute this message to their AOC simultaneously in order for coordination to take place with the C-ATSU.

The D-ALERT service consists of the following types of exchanges:

- Downlink aircraft emergency or abnormal situation indication

The D-ALERT service uses addressed communications.

2.2.2.6.2 Urgent Contact (URCO)

The Urgent Contact (URCO) service enables an ATSU to establish urgent voice or data communications contact with a Flight Crew or for a Flight Crew to contact an ATSU when other forms of communications have failed.

The URCO service consists of the following types of exchanges:

- Uplink or downlink of urgent voice or data contact message

The URCO service uses addressed and/or broadcast communications.

2.2.2.7 Delegated Separation Services

2.2.2.7.1 In-Trail Procedure (ITP)

The ITP service requires both the ACL and SURV services. The ITP service is initiated by issuing an ACL instruction to one aircraft to perform a climb, descent, or station-keep relative to a target aircraft. The aircraft performing the ITP instruction receives the SURV data from the target aircraft and displays the position information on the Cockpit Display of Traffic Information (CDTI). The Flight Crew receiving the ITP instruction identifies the target aircraft using the CDTI and assumes separation responsibility with the target aircraft during the procedure.

The ITP service consists of the following types of exchanges:

- SURV aircraft position and intent
- ITP ACL instruction(s)

The ITP service uses both addressed (ACL) and broadcast (SURV) communications.

2.2.2.7.2 Merging and Spacing (M&S)

The M&S service requires both the ACL and SURV services. The M&S service is initiated by a Controller issuing an ACL instruction to one aircraft to perform a merging and spacing manoeuvre relative to a target aircraft. The aircraft performing the M&S instruction receives the SURV data from the target aircraft and displays position information on the CDTI. The Flight Crew receiving the M&S instruction assumes separation responsibility with the target aircraft during the procedure.

The M&S service consists of the following types of exchanges:

- SURV aircraft position and intent
- M&S ACL instruction(s)

The M&S service uses both addressed (ACL) and broadcast (SURV) communications.

2.2.2.7.3 Crossing and Passing (C&P)

The C&P service requires both the ACL and SURV services. The C&P service is initiated by a Controller issuing an ACL instruction to one aircraft to perform a crossing and passing manoeuvre relative to a target aircraft. The aircraft performing the C&P instruction then receives the SURV data from the target aircraft and displays the position information on the CDTI. The Flight Crew receiving the C&P instruction assumes separation responsibility with the target aircraft during the procedure.

The C&P service consists of the following types of exchanges:

- SURV aircraft position and intent
- C&P ACL instruction(s)

The C&P service uses both addressed (ACL) and broadcast (SURV) communications.

2.2.2.7.4 Paired Approach (PAIRAPP)

The PAIRAPP service requires both the ACL and SURV services. The PAIRAPP service is initiated by an ACL instruction to a pair of aircraft to perform a simultaneous approach. Both aircraft performing the simultaneous approach exchange SURV data and display position data on the CDTI. The Flight Crews assume separation responsibility with the partner aircraft during the procedure.

Note: Very high SURV update rates may be required.

Typically, COTRAC agreements would bring aircraft to the point in their approaches where minimal standard separation is reached. Upon initiation of PAIRAPP, the

COTRAC service would be terminated. PAIRAPP would then allow the participating aircraft to reduce to and maintain spacing necessary to conduct closely-spaced simultaneous parallel approaches to runways with as little as 750 feet spacing between runway centrelines without requiring Flight Crews to visually acquire either the runway or their partner aircraft.

The PAIRAPP service consists of the following types of exchanges:

- SURV broadcasts of aircraft positions and intent
- PAIRAPP ACL instructions

The PAIRAPP service uses both addressed (ACL) and broadcast (SURV) communications.

2.2.2.8 Miscellaneous Services

2.2.2.8.1 Air-to-Air Self Separation (AIRSEP)

The Air-to-Air Self Separation (AIRSEP) service exchanges data between aircraft to ensure separation in the AOA domain, without the aid of ground ATC support. AIRSEP requires automated airborne algorithms that detect or estimate the probability of conflicts with other flight trajectories, airspace, or weather restrictions along the intended route of flight.

The AIRSEP service consists of the following air-air exchanges:

- **Trajectory Intent Exchange:** Automatic interrogation of the projected intent to a sufficient distance beyond a conflict point to determine the required encounter-specific separation.
- **Conflict Negotiation:** Machine-machine trajectory modification generated by on-board automation. Trajectories are exchanged until resolution is achieved or until a parameter time remaining to resolve the conflict is reached, whichever occurs first. The negotiated trajectory is provided to the Flight Crew for approval and execution.
    - **Resolution Accept/Confirmation:** Response message ensuring positive confirmation of the negotiated trajectory.

The AIRSEP service uses addressed and/or broadcast communications.

2.2.2.8.2 Automatic Execution (A-EXEC)

The A-EXEC service provides an automated safety net to capture situations where encounter-specific separation is being used and a non-conformance FLIPINT event occurs with minimal time remaining to resolve the conflict. Subject to local implementations, aircraft that support the A-EXEC service are separated based on encounter-specific conditions. When non-conformance occurs, triggering an imminent loss of separation, the ground automation system generates and sends a resolution to the aircraft for automatic execution without the Flight Crew or Controller in the loop. Once an A-EXEC instruction has been issued and executed, additional A-EXEC, ACL, COTRAC, or voice services may be used as required.

The A-EXEC service consists of the following types of exchanges:

- Uplink of clearance instruction

The A-EXEC service uses addressed communications.

Note: A-EXEC is only applicable on a very limited basis in critical situations.

The absence of a "human in-the-loop" during the execution of A-EXEC, results in significant safety and security concerns.

2.3 Aeronautical Operational Control (AOC) Services

AOC is an important element of ATM and is needed for continued efficient operation by airspace users. AOC services are concerned with the safety and regularity of flight and as such are defined in Annex 10 of the ICAO Convention. AOC applications involve voice and/or data communication between the aircraft and the AOC centre, company, or operational staff at an airport.

Requirements for AOC voice, including communication with the airspace user operations centres and between aircraft, will continue a downward trend as use of data communication increases. However, AOC voice will continue to be required.

The bulk of AOC message traffic uses data communication. It is assumed that the growth of air traffic, the increase in number of messages per aircraft, and the increase in the size of a message will result in increased AOC data communications load. There are two areas of communication that are anticipated to result in especially high communication loads: communications at the gate and airborne real-time monitoring.

2.3.1 AOC Voice Services

There are two types of voice communications services. The first is an addressed voice service that handles Flight Crew-Operations Centre communications. The second is either a party-line or broadcast voice service that handles Flight Crew-Flight Crew voice communications. The party-line/broadcast service is especially applicable in oceanic and remote regions to aid in situational awareness.

2.3.2 AOC Data Services

This section contains descriptions of the AOC data communication services that are expected to be in use during Phase 1 and Phase 2.

2.3.2.1 AOC Data Link Logon (AOCDLL)

The Flight Crew activates the data communication system and enters the required flight identification information into the logon page in order for AOC to respond with the correct information. The AOCDLL provides an indication to AOC that the Flight Crew has arrived on-board the aircraft and are prepared to receive AOC generated information in order to conduct the flight.

2.3.2.2 Out-Off-On-In (OOOI)

Movement Service messages including Out-Off-On-In (OOOI) report data are automatically routed to the AOC Movement Control System. This service is a one-way downlink from the aircraft to AOC to report significant points in the flight's progress.

2.3.2.3 Notice to Airmen (NOTAM)

The NOTAM service provides information to alert the Flight Crew in the event of the following:

- Hazards such as air-shows and parachute jumps
- Closed runways
- Inoperable radio navigational aids
- Military exercises with resulting airspace restrictions
- Inoperable lights on tall obstructions
- Temporary erection of obstacles near airfields (e.g., cranes)

The Flight Crew activates this service.

2.3.2.4 Free Text (FREETEXT)

The FREETEXT service includes miscellaneous uplinks and downlinks via textual messages between the cockpit and AOC or other ground based units. This service does not include cockpit-to-cockpit exchanges.

2.3.2.5 Textual Weather Reports (WXTEXT)

The WXTEXT service is initiated by Flight Crew requests for airport weather information. The WXTEXT service includes Meteorological Aerodrome Reports (METARs) and Terminal Area Forecasts (TAFs). The AOC responds to Flight Crew requests by delivering the requested weather information to the cockpit.

2.3.2.6 Position Report (POSRPT)

The POSRPT service includes automatic downlink of position during the climb, cruise, and descent portions of the flight. The primary purpose of this service is delivery of position reports at required waypoints for use in AOC tracking systems. During all phases of flight, but principally En Route, the Flight Crew can also manually initiate the POSRPT service for such things as in-range reporting.

2.3.2.7 Flight Status (FLTSTAT)

The FLTSTAT service includes, for example, malfunction reports including fault-reporting codes that allow maintenance and spares to be pre-positioned at the parking stand after landing. Fault reporting can be done manually or can be automatically sent when triggered by an event.

2.3.2.8 Fuel Status (FUEL)

The FUEL service downlinks fuel status En Route and prior to landing. This service allows ground services to dispatch refuelling capability promptly after landing. The Flight Crew also reports the fuel status upon specific request from the AOC.

2.3.2.9 Gate and Connecting Flight Status (GATES)

The GATES service for passengers and Flight Crew includes manual and automatic uplink of connecting flights, estimated time of departure (ETD), and gate assignments before landing. Information about rebooking may also be included in case of late arrival or cancelled flights.

2.3.2.10 Engine Performance Reports (ENGINE)

The ENGINE service is used to downlink aircraft condition monitoring system (engine and systems) reports in real time, automatically and on request. This is usually done in the En Route phase.

2.3.2.11 Maintenance Problem Resolution (MAINTPR)

Using the MAINTPR service, maintenance personnel and a Flight Crew are able to discuss and correct technical problems while the aircraft is still airborne. Although voice is customarily used for the discussion of the problem, this service may be used to provide the instructions for problem resolution as a text message between maintenance personnel and Flight Crew.

2.3.2.12 Flight Plan Data (FLTPLAN)

The FLTPLAN service provides the operators with the ability to request and receive the AOC-developed flight plan for comparison to that assigned by ATC and for loading into avionics. AOC flight plans have more information than flight plans filed with ATS.

2.3.2.13 Load Sheet Request/Transfer (LOADSHT)

Upon downlink request, the Load Sheet Control System uplinks planned load sheet and cargo documentation in the LOADSHT service. A number of data calculations relating to aircraft loading, takeoff, and landing are required to enhance safety and/or meet aviation regulations. The load sheet includes weight and balance information which insures resultant weights and centre of gravity are within the performance limits of the aircraft. A preliminary load sheet is transferred right after an AOCDLL. A final load sheet is typically transferred just before pushback, but can be transmitted as late as just before takeoff. The load sheet will also include a passenger manifest & fuel status.

A takeoff data calculation (TODC) is provided for the minimum takeoff speeds and flap settings. The calculation takes into account weights, aircraft technical parameters (e.g., thrust), and environmental parameters (e.g., wind, temperature, density altitude and runway length or conditions). If the TODC is sent before the final load sheet or if the planned takeoff runway is changed, an updated TODC may be required.

A landing data calculation (LDC) is a calculation similar to the TODC. The LDC is transmitted towards the end of the flight in the TMA domain.

2.3.2.14 Flight Log Transfer (FLTLOG)

The FLTLOG service is used to track the aircraft's flight times, departure and destination information, etc. Flight log information may be manually requested by the AOC or automatically downlinked.

2.3.2.15 Real Time Maintenance Information (MAINTRT)

The MAINTRT service allows aircraft parameters to be sent to the airline maintenance base in real-time to monitor the operational status of the aircraft and to troubleshoot problems identified during the flight. Information could include engine data, airframe systems, etc. This service allows information to be obtained more quickly than the normal maintenance data acquisition via on-board recorders. It is typically event driven, triggering a flow of information until resolution is achieved. The maintenance personnel may request other parameters to be downlinked in addition to those triggered by the event.

2.3.2.16 Graphical Weather Information (WXGRAPH)

The WXGRAPH service sends weather information to the aircraft in a form that is suitable for displaying graphically on displays in the cockpit (e.g., vector graphics). This service provides advisory information which supplements or replaces the textual weather information available in current AOC services. Graphical weather information is expected to be more strategic in nature and will supplement on-board tactical weather radar which has inherent range and display limitations.

2.3.2.17 Real-time Weather Reports for Met Office (WXRT)

With the WXRT service, information derived by the aircraft on the environment in which it is flying (e.g., wind speed and direction, temperature) can be sent automatically in real-time to weather forecasting agencies to help improve predictions.

2.3.2.18 Technical Log Book Update (TECHLOG)

The TECHLOG service allows the Flight Crew to complete the aircraft's technical log electronically and send the updated log to the maintenance base. Information regarding the technical status, physical condition, and trouble reports of the aircraft can therefore be obtained much more quickly so that any remedial action can be taken at an early stage.

2.3.2.19 Cabin Log Book Transfer (CABINLOG)

The CABINLOG service allows the cabin crew to complete the aircraft's cabin-equipment log electronically and send the updated log to the AOC. Information regarding the status of the cabin equipment can therefore be obtained much more quickly so that any remedial action can be taken at an early stage.

2.3.2.20 Update Electronic Library (UPLIB)

The Electronic Library will replace many of the paper documents currently required to be carried in the cockpit (e.g., Aircraft Manual, Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARs), and Airspace Charts). The UPLIB service enables this information to be updated electronically either by request or automatically. The transmitted information will be used to update various avionic systems (e.g., an Electronic Flight Bag [EFB] device). As such, this service carries safety-related information used for navigational purposes by the Flight Crew/Aircraft.

2.3.2.21 Software Loading (SWLOAD)

The SWLOAD service allows new versions of software to be uploaded to non-safety related aircraft systems whilst the aircraft is at the gate.

3 OPERATIONAL CONCEPT, ENVIRONMENT, AND SCENARIOS FOR COMMUNICATIONS

3.1 Introduction

This section describes the ATM operational concepts and operating environment considered in the COCR. The ATM concepts will increase the efficiency of air traffic management, thereby allowing air traffic growth. Operational service capabilities are implemented in phases to support the operational concepts. Each of these phases increases airspace capacity. For each phase, a typical scenario is provided to demonstrate how voice and data services would be used.

The following information applies to Section 3.

- The terms Executive, Planning, Tower Runway, Ground, and Clearance/Ramp Controllers are used to generically differentiate Controller roles and typically represent Controllers working a sector or individual positions in an airport tower. Locally, these Controllers may be referred to by various names, e.g., Surveillance, R-Side, or Radar for Executive Controller; Sector Planner, D-Side, Data, or Co-ordinator for Planning Controller; or Local or Flight Data for Tower positions.
- The information contained in the following scenarios is based on regions of the world with high-density airspace. Regions of the world with lower density of air traffic may choose to continue with voice-based procedures but could benefit from transition to a more data communications-based operation for global harmonisation and aircraft procedural consistency.
- When data communications is used, voice-based procedures may be used as an alternative form of communication depending on the dynamics of the situation.
- The services (including acronyms) referred to in the following sections are defined and described in the acronym list and detailed in Section 2 based on the EUROCONTROL Operational Requirements for Air/Ground Co-operative Air Traffic Services [3] plus other services developed from additional sources. The concept is then extrapolated to reflect the future scenarios associated with the Phase 1 and 2 timeframes beyond that which the reference documents provide.
- The services listed in the following scenarios are not all-inclusive of the services listed in Section 2. An acronym in **bold** type indicates that a message transaction process occurs using the services defined in Section 2.

3.2 Phase 1 Concept

To support the anticipated growth of aircraft traffic, all ATM stakeholders (e.g., commercial aviation, general aviation, military users, neighbouring Air Navigation Service Providers (ANSPs), regulators, airport operators, and other governing entities) must work together in a collaborative manner to plan and execute their aviation operations. All stakeholders may participate in, and benefit from, the advantages of using a wide network of information. As part of this network of information, the operations planning process aims to maintain a continuous balance between demand and capacity and to identify system constraints. Stakeholders have access to the planning process through a common network; they are able to retrieve information to be used for their tailored purposes or make a query to identify possible constraints and, in a collaborative manner, use the information to negotiate and develop consensus on possible opportunities, plan new operations or mitigate potential constraints.

The ATM system is continuously evolving. The focus of development and change until this point in time has been on the planning process, where communication and information exchange among ATM stakeholders have become increasingly more important. Decision-making processes have become more collaborative as common situational awareness among the ATM stakeholders has developed. The roles and responsibilities of the ATM stakeholders are evolving from controlling to managing traffic. The paradigm change from “management by intervention” to “management by planning and intervention by exception” begins in the Phase 1 ATM environment.

The most significant evolution completed in this period is flight planning through the implementation of a seamless layered planning process. Basic layered planning existed earlier, but by the time of Phase 1 it has started to evolve into a continuous planning process. Under Phase 1, the layered planning process generally satisfies an agreed and stable demand and capacity balance. This is accomplished through demand and capacity determination, active demand and capacity management, and re-planning for optimisation. These tasks continue across all layers of planning and are not restrained by the time constraints of the individual layer.

The layered planning process will not be described in detail as the focus of this document is on the aspects or capabilities that directly impact the demand on the digital aeronautical communication system (air-ground and air-air communications). However, application of the layered planning process will generate the following benefits:

- An improved picture of the predicted traffic situation enabling all ATM stakeholders to analyse and develop their business cases
- The active involvement of all ATM stakeholders in the decision-making process also supporting and facilitating the use of company planning and company decision support tools
- A collaborative decision-making process encompassing the ATM stakeholders concerned
- Communication of real-time events enabling ATM stakeholders to take advantage of changing conditions in real time, thus helping them to achieve their preferences

The Planning Controller represents the lowest planning level within the layered planning process. The Planning Controller’s primary task is to plan and establish a conflict-free and efficient traffic flow within his/her area of responsibility. Because of his/her extended geographical and time-related planning horizon, he/she is able to act early on expected complexity and conflicts and look for efficient solutions. Furthermore, he/she is able to react more efficiently and flexibly to user requests, such as direct routings, prioritisation of individual flights, or special support for on-time arrivals.

A gradual shift in emphasis from an Air Traffic Control (ATC) environment defined by tactical interventions towards an operating environment based on reliable planning is beginning. As a consequence, the role of Controllers is evolving into more of a monitoring and managerial role in certain areas. Examples of this change are seen in the beginning steps of pre-negotiated operations, where the Flight Crew executes a previously agreed-upon trajectory agreement. The Controller, however, retains the responsibility for separation or co-ordinates and issues instructions where responsibility is delegated to the Flight Crew for a specific procedure of limited duration (e.g., spacing). Consequently, the Flight Crew’s role has begun to change and now includes assumption of these responsibilities previously residing with the Controller. All this is supported by new or enhanced functions of the ATM system encompassing air and ground applications.

Operational changes are also being implemented for the management of ground movements. They are optimised to provide maximum use of the ground infrastructure, even in adverse weather conditions, by using new ATM system capabilities. The airspace structure is beginning dynamic adjustment of control sector boundaries according to demand, allowing for limited implementation of user-preferred trajectories.

All of the changes identified above, technical and operational, will have an impact on the business models of ATM stakeholders. The ATM stakeholders must cope with changing requirements on human skills, new and harmonised operational procedures that cross ATM stakeholder business boundaries, changing requirements on their systems, and newly implemented rules and regulations catering, for example, to environmental issues.

3.2.1 Phase 1 Environmental Characteristics and Conditions and Aircraft Performance Characteristics

This section describes the Phase 1 environmental characteristics and conditions. Table 3-1 provides the Phase 1 airspace characteristics categorised by domain. Table 3-2 provides the Phase 1 environmental conditions.

Note: The Phase 1 environmental characteristics for APT, TMA, and ENR are based on [2]. The Phase 1 environmental conditions are copied from [2].

	APT	TMA	ENR	ORP
Communication capability and performance	Voice is primary means of communication. Data is used for non-time-critical or routine communications	Voice is primary means of communication. Data is used for non-time-critical or routine communications	Voice is primary means of communication. Data is used for non-time-critical or routine communications	Data is primary means of communication. Indirect voice service used for non-routine and emergency communications
Navigation capability and performance	Precision Landing System Visual separation	Area Navigation (RNAV)/RNP 1	RNAV/RNP 4 Reduced Vertical Separation Minima (RVSM)	± 300 ft altimeter, RVSM, Minimum Navigation Performance Specification (MNPS), Inertial ±2 NM/hour drift rate, RNAV/RNP 10, RNAV/RNP 4
Surveillance capability and performance	Visual and voice communication Surveillance Monitoring	Aircraft Collision Avoidance System (ACAS) Surveillance service	ACAS Surveillance service	ACAS, Time/speed-based verification, Distance-based verification, Lateral deviation monitor ADS-C
Separation (Horizontal)	Longitudinal 2 or 3 minutes or wake turbulence criteria, whichever is greater	2.5-5 NM	5 NM	Lateral: 60 NM (MNPS), 100 NM, 50 NM, or 30 NM Longitudinal: is time-based: 5/10/15 min, or Distance-based: 50 NM or 30 NM
Separation (Vertical)	Not available (N/A)	1000 ft	1000 ft 2000 ft RVSM	1000 ft 2000 ft RVSM
Traffic complexity	Complex with visual guidance	Complex route structure with complex arrival and departure routes	RNAV complex route structure	Composite separation, parallel tracks, crossing tracks

Table 3-1: Phase 1 Airspace Environmental Characteristics

Reference	Environmental Condition
C-ENV-1	In airspace where ATC data services are used, very high frequency (VHF) and/or ultra high frequency (UHF) voice services, as required by the operating rule, are available.
C-ENV-2	A controlled flight is under the control of only one controller at a time.
C-ENV-3	Surveillance enables the controller to detect incorrect aircraft movement.
C-ENV-4	Flight plan submission and processing, per ICAO 4444.
C-ENV-5	Provision and use of data communications services, per ICAO 4444.
C-ENV-6	The airspace to which the clearance pertains is protected until the controller receives the response.
C-ENV-7	The users are properly trained to use data communications.
C-ENV-8	Where a D-ATIS supplements the existing availability of Voice-ATIS, the information shall be identical in both content and format to the applicable Voice-ATIS broadcast.
C-ENV-9	The flight crew executes received instructions/clearances and updates onboard avionics in a timely manner.

Table 3-2: Phase 1 Services Environmental Conditions

Table 3-3 provides the Phase 1 aircraft performance characteristics for each domain. Phase 1 aircraft performance assumptions and characteristics include the following:

- Space and Special-Use Vehicles are outside the scope of the FRS.
- Aircraft travelling over land masses (e.g., surface, TMA, En Route) will be limited to air speeds below Mach 1 (speed of sound) to prevent sonic booms (e.g., 0.95 mach).
- Air-Air speeds are based on the closing speed of two jet aircraft in the same wind environment.

Parameter	APT	TMA	ENR/ORP
Max Gndspeed (Knots True Airspeed [KTAS])	160	360	850
Max Airspeed (KTAS)	160	250	600
Max Air-Air (KTAS)	N/A	500	1200
Max Acceleration (m/s^2)	5	50	50

Table 3-3: Phase 1 Aircraft Performance Characteristics

3.3 Phase 1 Scenario

As noted earlier, an acronym in **bold** type indicates that a message transaction process occurs using a service defined in Section 2.

3.3.1 Pre-Departure Phase in the APT Domain

The aircraft operator provides gate/stand information, aircraft registration/flight identification, and estimated off-block time to other users (e.g., Airport and ATC) via the ground-ground communications system. The Flight Crew prepares the aircraft for the flight and in particular provides the necessary inputs and checks in the Flight Management System (FMS). They activate the data communications system, which initiates a network connection establishment between the aircraft and ground systems, and send an AOC Data Link Logon **(AOCDLL)** to AOC. Aircraft and ground systems may exchange network keep-alive messages during the flight when there is no traffic for a period of time. Logon and contact with the ATSU automation system is performed by the Data Link Logon (**DLL)** service. The DLL contains the address and application data required to enable addressed data communications services. The Flight Crew requests the Flight Plan (**FLTPLAN**) from AOC and enters the AOC-provided flight plan data into the FMS. The Flight Crew consults relevant aeronautical information (e.g., Planning Information Bulletins, NOTAMs, and Aeronautical Information Charts) concerning the flight. Real-time information on the flight's departure is now available in the ATSU automation system.

The Flight Crew initiates a request for a Data Link Operational Terminal Information Service (**D-OTIS)** contract for the departure airfield. The Flight Information Service (FIS) system response provides all relevant information for the weather, Automatic Terminal Information Service (ATIS), and field conditions, plus the local NOTAMS.

The Flight Crew requests a departure clearance from the system via the Departure Clearance (**DCL)** service. The tower sequencing system integrates the flight into an overall arrival/departure sequence, taking into account any Air Traffic Flow Management (ATFM) constraints, and assigns the appropriate runway for take-off. The Controller, supported by available automation, provides the **DCL** response including an updated calculated take-off time (CTOT) via data communications to the Flight Crew. The **DCL** response is checked against what was provided from AOC for consistency, and any changes are updated in the FMS. The ATSU automation updates the integrated Arrival/Departure Manager system (AMAN/DMAN) and ATC centres along the route of flight with the CTOT. A suitable time after delivery of the **DCL** response, the ATSU performs a Flight Plan Consistency (**FLIPCY)** check of the FMS flight plan data. Should an aircraft be capable of performing the FLIPINT service, this could be used to satisfy the consistency check.

In low visibility conditions, the Flight Crew may also use the Data Link Runway Visual Range (**D-RVR)** service to request RVR information for the departure and the destination airports. For data-link equipped aircraft preparing to taxi, the current graphical picture of the ground operational environment is uplinked and loaded using the Data Link Surface Information Guidance (**D-SIG)** Service.

The Loadsheet Request (**LOADSHT**) is sent to AOC. The Loadsheet Response (**LOADSHT)** with the "dangerous goods notification information" and the last minute changes to the weight and balance of the aircraft are sent by the AOC and are automatically loaded into the avionics. Some of this data will remain available for the Data Link Alert (**D-ALERT)** service throughout the flight, should an emergency occur. During this pre-flight phase, the Data Link Flight Update (**D-FLUP)** service is accessed to see if there are any delays/constraints anticipated to the preparations for the flight. The Flight Crew specifies preferences that should be considered by the Controllers using the Pilot Preferences Downlink (**PPD)** service.

The Flight Crew requests a "Start Up and Push Back Clearance" via the Data Link Taxi (**D-TAXI)** Service. The ATSU sequencing system calculates the planned taxiing time and, after comparison with the issued CTOT, issues the **D-TAXI** response. For appropriately equipped aircraft, the **D-TAXI** route is superimposed over the **D-SIG** information previously received. The Flight Crew pushes back and starts up the engines in accordance with Airport procedures. The push back generates an Out-Off-On-In (**OOOI)** message to AOC advising that the flight has left the gate/stand.

As the aircraft pushes back, the Surveillance (**SURV)** service is activated and continues for the duration of the flight. The Advanced Surface Movement Guidance and Control System (A-SMGCS) picks up the surveillance message and associates the aircraft with the FDPS flight plan. The ATSU's sequencing tool updates the times for the overall arrival/departure sequence. For short-haul flights (<250 NM), the updated information is provided to the integrated AMAN at the arrival airport.

The conflict probe system of the first ATSU analyses any potential conflicts caused by the proposed trajectory of the departing flight and informs the Planning Controller concerned with the flight. The Planning Controller uses the information to update the planning process.

3.3.2 Departure Taxi in the APT Domain

The Flight Crew requests the **D-TAXI** clearance from the tower ground Controller. The tower ground Controller issues the **D-TAXI** response. The Flight Crew manoeuvres the aircraft according to the taxiing instructions. The tower ground Controller monitors the taxiing of the aircraft assisted by A-SMGCS and intervenes if required.

The ATSU automation system generates a transfer message for the tower ground Controller that control will be passed to the tower runway Controller frequency automatically via ATC Communication Management (**ACM**) on reaching the handover point. The tower runway Controller issues the "Line Up and Wait Clearance" by voice to the Flight Crew in accordance with the traffic situation. The tower runway Controller issues the "Take Off Clearance" via voice to the Flight Crew in accordance with the traffic situation.

The ATSU automation system forwards the **DLL** information via ground-ground communications to subsequent ATSUs so that data communications with respective downstream Controllers can be conducted.

The Flight Crew commences the take off run. The ATSU automation system detects that the aircraft is airborne and disseminates that information to the flow manager, neighbouring sectors' and centres' Planning Controllers, and air defence and makes it available for other users. An **OOOI** message is sent to AOC that the aircraft is airborne.

The ATSU automation system generates a transfer message for the tower runway Controller and uses the **ACM** service to provide the frequency to contact the next sector Executive Controller to the aircraft via data communications.

3.3.3 Departure in the TMA Domain

When the aircraft is airborne, the Flight Crew contacts the first sector Executive Controller using voice. The ATSU automation system determines the exit conditions from the first sector. The conflict probe checks to see if the entry conditions into the next downstream sector are conflict free and forwards coordination information to the downstream sector.

The Executive Controller issues instructions via the ATC Clearances (**ACL**) service (via voice or data, depending on the tactical nature of the situation) to the Flight Crew to achieve the exit conditions to enter the next sector and provides this clearance information to the ATSU automation system. The conflict probe provides the Planning Controller and Executive Controller with information about potential interactions with other aircraft or airspace for up to 30 minutes from present position. The Controller team takes necessary action to alleviate these conflicts using the appropriate services. The Flight Crew flies the aircraft according to the instructions given. The System Access Parameters (**SAP**) service is initiated by the ATSU automation system, and the downlinked information is provided to the various ground components (e.g., for smoothing of trackers) or on request for display of parameters to Controllers. The ATSU automation system monitors the aircraft behaviour in accordance with the given clearances. The tracking system issues warnings to the

Executive Controller in case of non-compliance. The Executive Controller intervenes if the situation requires action. The tracking system uses the ADS and radar data to monitor whether the aircraft performance is in accordance with the ground-predicted trajectory and updates the trajectory where necessary.

The Executive Controller transfers control of the aircraft to the next sector Executive Controller. The data communications processing system provides the next frequency to the Flight Crew via the **ACM** service and transfers the data communications capability management to the next sector/ATSU. A new network connection is established between the aircraft and an En Route domain ground system before the connection with the departure TMA domain ground system is released.

3.3.4 Operations in the ENR and ORP Domains

Note: In Phase 1, a typical continental flight will pass through four En Route facilities. Long haul flights will traverse numerous En Route facilities. The number of sectors traversed within each En Route facility is typically two. The exchanges that occur from a communications stand-point are the same in each En Route facility, so the following description does not specify inter- vs. intra-facility transfers or ATSU automation system events unless necessary for clarity of the scenario.

The ATSU automation system confirms/sets the exit/entry conditions with the sectors in the En Route phase. At each entry into a subsequent ATSU, **FLIPCY** is performed to verify the FMS route against what is held in the ATSU FDPS. The ATSU automation system establishes a Flight Plan Intent **(FLIPINT)** contract (e.g., periodic or event) with equipped aircraft while in each ATSU's area of jurisdiction to ensure consistency between on-board routes against ATSU FDPS routing. The Executive Controller decides and performs, or has the Planning Controller perform, **ACL** as necessary and initiates handovers to the next sector/ATSU. The ATSU automation system supports handover by communicating the event to the Flight Crew and the downstream sector/ATSU via **ACM**. The Flight Crew contacts or monitors the frequency of the receiving sector Executive Controller when the handover is performed. Meanwhile, the aircraft reaches top of climb and generates an Engine Performance Report (**ENGINE**) to the AOC. The Controller team accesses the **PPD** information from the aircraft to determine if any of the Flight Crew preferences affect or could improve the planned trajectory. The Flight Crew initiates an ACL to request a modification to the current trajectory. The Planning Controller assesses the request against the conflict probe. If no conflicts are found, and after informing the Executive Controller, the response is sent via **ACL**. An aircraft system notices a minor fault in one of the cross bleed valves that generates a Flight Status (**FLTSTAT**) message to AOC for maintenance action upon arrival.

During this phase of flight, the Flight Crew initiates the request for a Downstream Clearance **(DSC)** with the Downstream-ATSU (D-ATSU) for the Oceanic/Remote portion of the flight. The D-ATSU receives this request and determines whether the requested profile can be approved. In order to issue the clearance for the Oceanic/Remote portion of the flight, a change to the aircraft's current trajectory is necessary. The Planning Controller in the D-ATSU co-ordinates the changed entry point with the Controlling-ATSU (C-ATSU) Planning Controller. The result is provided to the D-ATSU Planning Controller for authorisation, and the **DSC** response is sent to the aircraft. The required change to the current trajectory to comply with the DSC is co-ordinated with the Executive Controller in the C-ATSU, is then sent to the aircraft via **ACL**, and an update is provided to the flight data processing system.

Prior to entry into the oceanic/remote domain, a weather report is provided to the Planning Controller indicating that moderate to severe turbulence may be expected over this portion of the flight. This information is sent to the aircraft via the Data Link Significant Meteorological Information **(D-SIGMET)** service. A new network connection is established between the aircraft and the Oceanic/Remote domain ground system before the connection with the En Route domain ground system is released.

The aircraft progresses through the Oceanic/Remote domain. The Flight Crew requests a more efficient altitude via **ACL**. Due to traffic, the **ACL** response includes the requirement to execute an In-Trail Procedure **(ITP)** using **SURV** information on the flight deck display between a pair of equipped aircraft. The progress of the flight is monitored by **FLIPINT**. Any events that cause the aircraft to be in non-compliance with the planned trajectory are communicated with appropriate alerting to the Executive Controller. Before the aircraft returns to the En Route domain, a new network connection is established between the aircraft and the En Route domain ground system before the connection with the Oceanic/Remote domain ground system is released.

The ATSU automation system recognises the position of the aircraft approaching the En Route domain and sets the exit conditions (target time) taking into account restrictions at the destination airport (if applicable in this sector). The AMAN calculated time is sent to the aircraft via the Arrival Manager Information Delivery **(ARMAND)** service and any modifications to the aircraft's trajectory are communicated via **ACL**. The aircraft position causes a Fuel Status (**FUEL**) message to be sent to AOC.

The conflict probe system provides the Planning Controller and the Executive Controller information about potential conflicts with other aircraft within a specified time (e.g., the next 15 minutes).

The Planning Controller analyses interactions with other aircraft that are reported to him/her by the conflict probe system. The Planning Controller probes "what-if" solutions for interactions. The conflict probe system may offer alternatives to the existing route, the Planning Controller assesses these alternatives, and the alternatives are provided via the Dynamic Route Availability **(DYNAV)** service for Flight Crew assessment. The Planning Controller enters the Flight Crew-selected alternative and updates the flight trajectory in the ATSU automation system. The Executive Controller is notified about the required change to the trajectory of the aircraft and issues the **ACL** instructions to the Flight Crew to achieve exit conditions to enter the next sector.

The Planning Controller, in coordination with the Executive Controller, occasionally issues instructions by data communications to the Flight Crew via **ACL** for cases where a manoeuvre is planned at a later stage (e.g., >2 minutes from current flight position). Otherwise, the Executive Controller provides instructions via **ACL** (voice or data, as determined by the tactical nature of the situation). The Flight Crew flies the aircraft according to the instructions given. The ATSU automation system recognises the aircraft's position relative to exiting the ATSU, compiles a Data Link Operational En Route Information Service **(D-ORIS)** report specific to the remaining portion of the area to be over-flown, and sends it to the aircraft.

The ATSU automation system uses the **SURV** and radar information to monitor that the aircraft behaviour is in conformance with the given clearances and, in case of non-conformance, issues warnings to the Executive Controller who intervenes via voice or data if a situation requires action.

The Executive Controller initiates a transfer of the aircraft to the next sector. The data communications processing system provides the next frequency to the Flight Crew via **ACM** and transfers the air-ground data communications services to the next sector.

The AMAN system notifies the Planning Controller and the Executive Controller about Top of Descent (TOD) at a time parameter prior to the TOD position. The conflict probe indicates a conflict will occur if the aircraft is to comply with the TOD calculation. A Merging and Spacing **(M&S)** operation is required to mitigate the conflict. As the Aircraft reaches the TOD position, an **ACL** instruction containing **M&S** instructions is issued to implement the needed trajectory. An **ARMAND** is initiated containing the Standard Terminal Arrival Route (STAR) allocation, runway for landing, and AMAN constraints.

Prior to entry into the arrival TMA domain, a new network connection is established between the aircraft system and the arrival TMA domain ground system before the connection with the En Route domain ground system is released.

3.3.5 Arrival in the TMA Domain

The system updates AMAN with changes to the arrival sequence. AMAN calculates constraints by taking into account the actual traffic situation and makes the information (time to lose/gain or hold) available to the concerned Planning Controller and Executive Controllers in upstream sectors/ATSUs. If required, the conflict probe system calculates a conflict-free alternative trajectory for the flight to comply with the AMAN constraints. The Planning Controller of the receiving sector checks the **PPD** service information to see if the conflict probe system-provided trajectory could be improved with these preferences. The Planning Controller accepts the proposal and co-ordinates the sending of the **ACL** instruction with the Executive Controller.

Based on the equipage and Flight Crew qualification information contained in the flight plan and data obtained via **SAP** and **PPD**, the Executive Controller determines which aircraft may execute a spacing application and issues **M&S** clearances to those aircraft via **ACL**.

At this time, the Executive Controller determines that the voice communication frequency in use has been blocked. In order to address this concern and free the voice channel for communications, the Planning Controller initiates an uplink of the ATC Microphone Check **(AMC)** service to all aircraft with which communication is required. Within moments, the blockage of the frequency is resolved, and the Executive Controller returns to voice communications for tactical instructions as necessary.

The flight information system provides requested Data Link Automatic Terminal Information Service **(D-ATIS)** information to the aircraft. The Aircraft Operator informs the Flight Crew via data communications and informs the Tower Ground Controller via ground-ground communications about stand/gate allocation.

The Executive Controller instructs the Flight Crew to descend. The FMS flies the aircraft according to the given instructions to the Initial Approach Fix (IAF) and generates a final Fuel Status (**FUEL**) report to AOC for refuelling planning. The tracking system uses **SURV** and radar data to monitor that the aircraft behaviour is in accordance with the given clearances and issues warnings to the Executive Controller in case of non-compliance. The Executive Controller can intervene via voice if a situation requires immediate action. The ATSU automation generates a **D-SIG** of the arrival airport surface.

The Executive Controller issues instructions to the Flight Crew to follow the calculated profile for final approach via **ACL**. The Executive Controller instructs the Flight Crew to monitor the Tower Runway Controller via **ACM**.

Prior to entry into the Airport domain, a new network connection is established between the aircraft system and the Airport domain ground system before the connection with the TMA domain ground system is released.

3.3.6 Arrival in the APT Domain

The Tower Runway Controller monitors the traffic situation and intervenes if required. The Tower Runway Controller issues the “Landing Clearance” to the Flight Crew via voice. The Tower System provides a recommended **D-TAXI** runway exit and the taxi-in route plan to the Tower Runway Controller. The Tower Runway Controller issues the **D-TAXI** instructions to the Flight Crew via **ACL,** which is overlaid on the D-SIG received prior to the final approach.

The Flight Crew lands the aircraft. The avionics detects touch down and disseminates this **OOOI** information to the AOC. The common network system makes this information available to other users. The A-SMGCS informs the Tower Runway Controller about the aircraft vacating the runway. The Tower Runway Controller instructs the Flight Crew to contact the Tower Ground Controller via **ACM** using voice or data whichever is more appropriate for the prevailing circumstances.

3.3.7 Arrival Taxi in the APT Domain

The A-SMGCS uses **SURV** and radar data to notify the Tower Ground Controller of the arrival sequence of the aircraft. The Tower Ground Controller uses the **D-TAXI** information to verify the aircraft’s assigned route from the landing runway nominated exit point to the gate/stand.

The Flight Crew contacts the Tower Ground Controller. The Tower Ground Controller clears the Flight Crew to follow the **D-TAXI** route plan. The Flight Crew manoeuvres the aircraft according to the instructions. The Tower Ground Controller monitors the traffic situation and intervenes if required. A-SMGCS calculates the target taxi-in period in real-time and uses a combination of **SURV** and radar information to monitor the traffic situation for the detection of potentially hazardous situations (e.g., conflict between aircraft, service vehicles, or obstacles) and issues warnings to the Tower Ground Controller as required.

When the aircraft arrives at the gate/stand, the aircraft sends an **OOOI** to the AOC who makes the information available for other users. AOC responds to the OOOI message with a Flight Log Transfer (**FLTLOG**) message to inform the crew of the next flight assignment. Data associated with the performance of the aircraft during flight and maintenance information are sent to the airline. The network connection between the aircraft and ground system is terminated.

3.4 Phase 2 Concept

The ATM system has been evolving constantly since introduction of Phase 1. All ATM stakeholders are fully participating in the Layered Planning Process, and the use of Collaborative Decision-Making (CDM) Processes is routine and commonplace. This has improved and widened the database for situational awareness and consequently makes the CDM Process faster and decreases uncertainty in decision-making.

The adherence to the concept of Layered Planning and the philosophy of CDM has driven the development of homogeneous procedures and the integration of systems and services for exchange of information. The integration has evolved over time from simple standardisation of interfaces in the beginning, via local "islands of integration" (e.g., at aerodromes), to a system-wide integration including air and ground elements as well as planning and executive levels.

In Phase 2, the organisation of the airspace is now either Managed or Unmanaged. The composition of Managed Airspace is structured routes surrounding arrival and departure airspace and airspace where user preferred trajectories are provided within given constraints. Unmanaged Airspace includes designated airspace where autonomous operations are conducted and airspace where ATS is not provided; this is illustrated in Figure 3-1. The degrees of freedom in flight planning and flight execution are governed by traffic density and level of equipage.

All traffic within Managed Airspace is known to the ATSU(s) involved. In Unmanaged Airspace, the ATSU may or may not be aware of the aircraft operations depending on the ground system architecture. However, as depicted in Figure 3-1, the airspace surrounding autonomous operations areas is managed and therefore the ATSU has knowledge of what aircraft entered or departed that airspace, but there is no ATC service being provided.

The level of service offered by the ATSU corresponds to the mode of operations in the different parts of the airspace. From a communications perspective, there is still a need for a communications buffer to exist on the managed/unmanaged airspace boundary in order for aircraft within managed airspace to be provided with separation assurance.

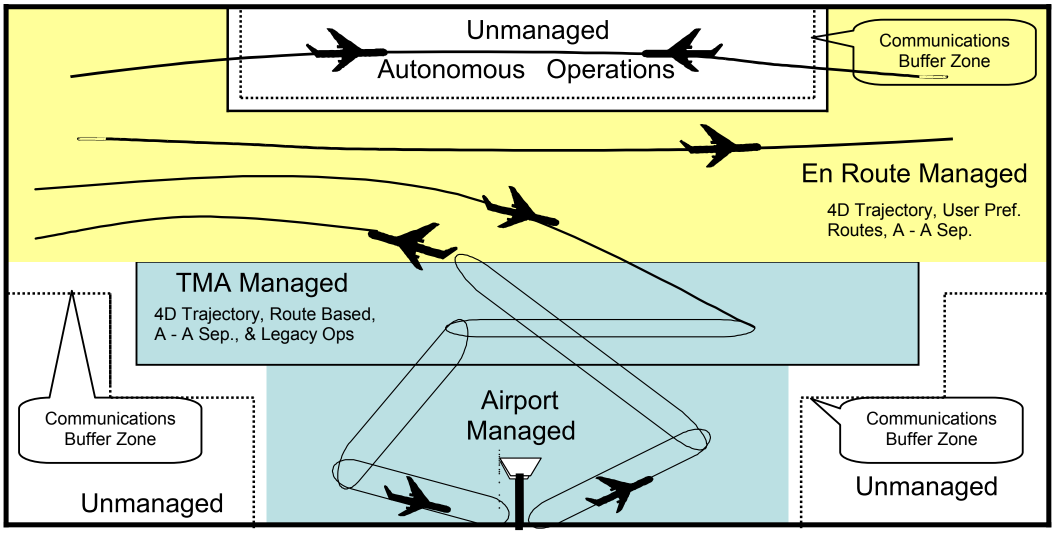

Figure 3-1: Phase 2 Airspace Organisation

In Phase 2, the integration of air-ground systems has evolved to an extent enabling common use of up-to-date information in a seamless and economical way. The information used in integrated systems comprises data from various sources, be it in the air or on the ground (e.g., FMS, AMAN), of different natures (e.g., intent data, forecast data), and of different urgency and priority (e.g., emergency communication, planning information). Common rules and standards are in place for the use of integrated systems and for the treatment of information and data. As communication and information exchanges between ATM stakeholders became more important, decision-making processes became collaborative as common situational awareness of the ATM stakeholders developed, and the roles and responsibilities evolved. The route based airspace design has predominantly been eliminated, replaced by spacing and sequencing applications. The size of Autonomous Operation areas has continued to increase. This paradigm change has defined the Phase 2 ATM environment.

The use of trajectory negotiations has become the norm. The evolution of Common Trajectory Coordination (COTRAC) has taken place, helped by the reorganisation of airspace and the emergence of avionics that allow the creation of 4-D trajectories, unrestricted by the number of points needed for their definition.

The implementation of the correct mix of services described in Section 2, along with supporting automation systems, has allowed an increase in the number of aircraft monitored by a given Controller team. Sector boundaries are now routinely changed to accommodate the division of labour amongst Controllers as traffic/weather conditions warrant. The communications resources associated with the airspace are all network-based and are reassigned as needed to provide coverage for the new sector layouts.

The most significant change to the operating concept previously described under Phase 1 is the commonplace use of transferred separation responsibility to Flight Crews from Controllers. Use of the cockpit display to provide Air Traffic Situation Awareness (ATSAW) of all aircraft in the vicinity and determine their short term intent has provided the basis for this routine sharing or transferring of separation responsibilities. In some regional implementations, separation standards in all domains have been reduced to that which is required to avoid the wake turbulence of other aircraft or to meet a particular time of arrival at a significant point. To ensure safety levels are maintained where encounter-specific separation is used, the ground and airborne systems must have the capability to detect conflicts, provide resolutions, and in rare cases implement the resolutions of the required manoeuvre by the aircraft, without human intervention, e.g., auto execution. The avionics capabilities now include conflict probing and resolution software used for managing conflicts when conducting autonomous operations.

Autonomous operations are performed in dedicated volumes of the managed airspace to accommodate the demand patterns. The dimensions of this airspace are tailored to the need for safe operation of aircraft in autonomous mode. This may encompass only a few flight levels in high-density airspace or bigger areas in low-density airspace, which offer the best possible freedom of movement. The aim will be to adjust the volumes of airspace allocated to Autonomous Operations to maximise the benefits for capable aircraft, while providing an incentive for aircraft operators with less capable aircraft to upgrade their avionics.

The Autonomous Operations Area (AOAs) is managed by ATC at the entry/exit points and within a buffer zone. If due to circumstances which occurred during the flight through the AOA, e.g., air-air conflicts, an aircraft is unable to comply with the COTRAC upon exit, communications with the appropriate ATSU must occur ~100 NM prior to departing the AOA. Aircraft wishing to participate in this self-separation operation must be equipped with the correct on-board automation allowing intent and conflict resolution sharing via “machine-to-machine” negotiations. The SURV application monitors other aircraft and triggers the conflict probe software when the need arises. The longer term projected intent is determined by interrogating the involved aircraft via a point-to-point data communications. The information shared provides enough 4-D positional information beyond the detected conflict zone to assess the best resolution. Upon analysing the positional information, on-board avionics co-ordinate manoeuvres that resolve the conflict and present the resolution in graphical form to the Flight Crew for activation. Some aircraft are capable of executing these manoeuvres without human intervention when set for that mode. Communications between the Flight Crews may or may not be necessary depending on the geometry of the conflict.

Where once a hub and spoke operation was the norm with many medium size (e.g., 100-140 passenger) aircraft, the industry now consists mainly of larger (e.g., 225 or more passenger) aircraft conducting trans- and inter-continental travel operating from the major metropolitan airports. Additionally, limited passenger services between airports and downtown locations using aircraft capable of vertical takeoff and landings (VTOL) are used on an increased basis.

Another revolution that has taken place is in the aircraft population. In some regions, a new breed of “microjets” has been developed to satisfy the need for unrestricted access to travel on an as-needed basis. The microjets, carrying 6-12 passengers, cater to short haul domestic travel, e.g., 750 NM, to/from your own home town or secondary suburban airports. They operate primarily from rural airports; basically on-demand, or with little to no prearranged travel planning required and they are competitively priced with the conventional commercial air transportation industry.

Some estimates[2] project that this type of aircraft can represent 40% of the daily traffic load.

Unmanned aerial systems (UAS) operating GAT are now common and routine. In the United States, estimates approach ~13,000 of these aircraft in operation in 2025 predominantly for military, cargo, agricultural or security operations.

This shift in the aircraft population has stretched the capacity of the ATM system. While it took some time to integrate these aircraft into the planning and decision-making process, once all shareholders understood how to work with the system, the increased burden of these operations became manageable. UASs, microjets, and all other aircraft operate alongside each other without any user needing to be treated differently.

A new type of Managed airport has also evolved. In order to assist in maintaining a higher degree of safety and efficiency at low to medium density airport environments, "virtual" towers where an automation platform replaces the Controller function issues weather and sequencing information based on the aircraft provided position and intent data. This provides a benefit to the local airport users as well as a saving to the ATSU in reduced resources required to provide that level of service.

Managing the flow of traffic has also become a routine task. The majority of traffic is metered from take off to arrival using four dimensional trajectory negotiations. Users need only notify the Controller if there is a need to change the trajectory, otherwise communication with the aircraft is mostly controlled by the System as it monitors the traffic.

CDM allows for aircraft to join together and create a "flight" of aircraft proceeding in the same direction to similar destinations. These operations are performed using similar procedures as is done with military operations flights today. Airborne display and automation systems provide assistance in the maintenance of separation from other aircraft in the flight.

The ATM system performance requirements have now evolved to the point where services such as **A-EXEC** require latency and availability levels that prevent catastrophic consequences. For example, in order to benefit from the services in this environment, the ATM system must receive non-conformance reports from aircraft that are projected to deviate by more than a specified time (e.g., 10 seconds [s]) from a previously co-ordinated longitudinal axis, or more than a specified lateral distance (e.g., 1000 feet). This criterion causes adjustments to the agreed **COTRAC** trajectory as environmental conditions cause non-conformance issues.

As data is now the primary means of communications, associated system developments have occurred to ensure highly reliable and deterministic provision of communications. Any intervention by Controllers is done using Phase 1 services.

[2] The U.S. JPDO has estimated that ~13,000 of these aircraft will be in operation in 2025.

3.4.1 Phase 2 Environmental Characteristics and Conditions and Aircraft Performance Characteristics

This section describes the Phase 2 environmental characteristics and conditions. Table 3-4 provides the Phase 2 airspace characteristics categorised by domain. Table 3-5 provides the Phase 2 environmental conditions.

	APT	TMA	ENR	ORP	AOA
Communication capability and performance	Data is primary means of communications. Voice is used for non-routine, failure recovery, or emergency communications.	Data is primary means of communications. Voice is used for non-routine, failure recovery, or emergency communications.	Data is primary means of communications. Voice is used for non-routine, failure recovery, or emergency communications.	Data is primary means of communications. Indirect communications is used for non-routine, failure recovery, or emergency communications.	Data is primary means of communications. Voice is used for non-routine, failure recovery, or emergency communications with other aircraft.
Navigation capability and performance	Precision Landing Systems Visual separation,	RNAV/RNP 0.5	RNAV/RNP 1 RVSM	RNAV/RNP 1 RVSM	RNAV/RNP 1
Surveillance capability and performance	Visual and voice communication. Surveillance Monitoring.	Surveillance service.	Surveillance Service using ADS-B & C. ACAS. Deviation monitor.	Surveillance Service using ADS-B & C. ACAS. Deviation monitor.	Airborne Surveillance using ADS-B and AIRSEP. ACAS.
Separation (Horizontal)	Longitudinal is encounter-specific criteria only, Lateral is 750 ft. between runway centrelines. CDTI.	Longitudinal is encounter-specific criteria only, Lateral is collision avoidance based. CDTI	Longitudinal is encounter-specific criteria only, Lateral is collision avoidance based. CDTI	Longitudinal is encounter-specific criteria only, Lateral is collision avoidance based. CDTI	Collision avoidance based. CDTI
Separation (Vertical)	N/A	1000 ft	1000 ft 2000 ft RVSM	1000 ft 2000 ft RVSM	Collision avoidance based. CDTI
Traffic complexity	Complex with visual guidance	Agreement based trajectories connecting to complex arrival and departure routes.	Agreement based trajectories.	Agreement based trajectories.	User-preferred trajectories until ready to depart the area, then resume agreement-based trajectories.

Table 3-4: Phase 2 Airspace Environmental Characteristics

Reference	Environmental Conditions
C-ENV-1	Data communication is primary for provision of ATS, except in the airport domain.
C-ENV-2	Voice communication is available.
C-ENV-3	Clearances/instructions may be issued by automation; without controller involvement. (All clearances are available for controller review).
C-ENV-4	With the exception of an A-EXEC, no trajectory changing clearance/instruction will be activated without Flight Crew action.
C-ENV-5	A controlled flight is under the control of only one controller at a time. (ICAO Annex 11: para 3.5.1)[48]

Reference	Environmental Conditions
C-ENV-6	Surveillance enables detection of incorrect aircraft movement.
C-ENV-7	The airspace to which the clearance pertains is protected until the response is received.
C-ENV-8	The users are properly trained to use data communications.
C-ENV-9	Where a D-ATIS supplements the existing availability of Voice-ATIS, the information shall be identical in both content and format to the applicable Voice-ATIS broadcast.
C-ENV-10	The flight crew executes received instructions/clearances and updates onboard avionics in a timely manner.
C-ENV-11	ACAS is available.

Table 3-5: Phase 2 Services Environmental Conditions

Table 3-6 provides the Phase 2 aircraft performance characteristics for each domain. The Phase 2 aircraft performance assumptions and characteristics are:

- Space and special-use vehicles are outside the scope of the FRS.
- Future speeds are based on the assumption that supersonic commercial aircraft may be in operation.
- Aircraft travelling over land masses (e.g., surface, TMA, En Route) will be limited to air speeds below Mach 1 (speed-of-sound) to prevent sonic booms, e.g., 0.95 mach.
- Air-Air speeds are based on the closing speed of two jet aircraft in the same wind environment.

Parameter	APT	TMA	ENR	ORP	AOA
Max Gndspeed (KTAS)	200	410	850	1465	790
Max Airspeed (KTAS)	200	300	600	1215	540
Max Air-Air (KTAS)	N/A	600	1200	2430	1080
Max Acceleration (m/s^2)	12.5	50	50	50	50

Table 3-6: Phase 2 Aircraft Performance Characteristics

3.5 Phase 2 Scenario

3.5.1 Pre-Departure Phase in the APT Domain

The mode of operation described under the Phase 1 scenario is now in common use for all aircraft. In particular, aircraft equipage has evolved to the point where every aircraft is now equipped with a cockpit display capable of high definition graphics. This allows the use of advanced concepts in ATM, based on graphical depictions of the surrounding aircraft situation, to be commonplace.

The issuance of a **DCL** now involves the negotiation of a highly constrained trajectory using the **COTRAC** service. The negotiation of the trajectory is done in accordance with the principles of CDM (involving the airspace user) to ensure that the airspace users' needs are considered. The final point in the clearance includes the required constraint of the arrival airport provided by the ground system.

3.5.2 Departure in the APT and TMA Domains

The aircraft follows the 4-D trajectory previously negotiated through **COTRAC**. The ATSU conflict probe system is now configured for up to a 2-hour look ahead from the active present position. The Controller team takes necessary action to alleviate these conflicts using the necessary services, predominantly the fine-tuning of the COTRAC agreement of involved/impacted aircraft.

3.5.3 Operations in the ENR, ORP and AOA Domains

As the use of the services and the nature of ATC have evolved, the communications requirements have evolved also. Trust in the system's performance has become commonplace. Routine exchanges are no longer needed. Everything the flight must do is embedded in the **COTRAC** agreement. Communications transfers via **ACM** occur automatically without Controller/Flight Crew involvement. **FLIPINT** agreements between the aircraft system and the ATSU automation system are now in place with all aircraft and reports are only generated when an event occurs beyond the parameters set in the **COTRAC** agreement. The aircraft's COTRAC trajectory takes into account the computational process of the arrival time constraint set by the AMAN system. Changes to this agreement are more in the context of overall trajectory maintenance.

However, when a non-compliance notification is received by the ATSU with less than 2 minutes remaining for resolution of the new conflict, two options are available. The first option is to notify the Controller with a warning message and allow the resolution to be achieved via voice.

The second option is ONLY applicable for aircraft equipped to do the **A-EXEC** service which allows for reduced separation e.g., 2 NM or encounter-specific separation. In this case, **A-EXEC** is initiated when the time remaining does not allow for the delays associated with human-in-the-loop performance. The ATSU automation must determine what the appropriate trajectory modifications are and initiate the transaction to the aircraft with an **A-EXEC** flag set to execute the manoeuvre without the Flight Crew acknowledgement.

In En Route/Oceanic/Remote airspace environments, Unmanaged Airspace may be designated for autonomous operations where self-separation applications are routinely conducted. These applications have followed a natural progression from earlier spacing applications, e.g., **M&S, C&P, and ITP**. Aircraft that have equipped for autonomous operations are managed via **COTRAC** up to the entry point into the AOA and are expected to comply with the existing **COTRAC** upon exiting the autonomous operations area. Any changes to the exit conditions require the aircraft to initiate a trajectory change request prior to departure from the AOA. When an aircraft detects a potential conflict, the **AIRSEP** service activates to determine the trajectory of the other aircraft involved, negotiates a solution, and provides the solution to the Flight Crew.

3.5.4 Arrival in the TMA Domain

Arriving at the entry point into the TMA, the COTRAC operation continues. When necessary due to the traffic density, aircraft are instructed via **ACL** to use the appropriate services to self-separate in the final approach phase from traffic landing on the same or closely spaced parallel runways. As the aircraft approaches the final approach course, the **PAIRAPP** service is initiated. This is the point where the COTRAC is terminated and the PAIRAPP service takes over to transfer separation responsibility from the Controller to the Flight Crew. These services, provided in combination, are the natural extension of the early spacing applications such as M&S used in Phase 1 En Route airspace. The arrival taxi phase is now established before the aircraft begins the final approach for landing. The **D-SIG** surface map and **D-TAXI** overlay is communicated in advance of the landing clearance so that the Flight Crew can determine any impacts to its configuration.

3.5.5 Arrival Taxi in the APT Domain

All the services introduced under the Phase 1 timeframe continue to be in use to some extent unless superseded by services such as the now mature COTRAC service. However, as airspace requirements and aircraft equipage increase, more aircraft are eligible for data services.

4 OPERATIONAL, SAFETY, AND SECURITY REQUIREMENTS

This section provides the operational and safety requirements for ATS data communications services and information security requirements for ATS and AOC data communications services.

Note: A safety assessment was not performed for the AOC services.

4.1 Operational Requirements

4.1.1 Service Level Operational Assessment

Table 4-1 and Table 4-2 provide operational assessment for each ATS service for Phase 1 and Phase 2 respectively. The column headers are defined as follows:

- Service: The acronym for the ATS service.
- Integrity: The required integrity to make the service usable.
- Continuity: The required continuity to make the service usable.
- Availability (Provision): The required service availability to make the service usable.
- Availability (Use): The required availability when using the service to make the service usable.

Service	Continuity	Integrity	Availability (Provision)	Availability(Use)
ACL	.99	10^{-2}	.999	.993
ACM	.99	10^{-2}	.999	.993
A-EXEC	-	-	-	-
AIRSEP	-	-	-	-
AIRSEP SURV	-	-	-	-
AMC	.99	10^{-2}	.999	.993
ARMAND	.99	10^{-2}	.999	.993
C&P ACL	.99	10^{-2}	.999	.993
C&P SURV	.99	10^{-2}	.999	.993
COTRAC	-	-	-	-
D-ALERT	.99	10^{-2}	.993	.993
D-ATIS	.99	10^{-2}	.999	.993
DCL	.99	10^{-2}	.999	.993
D-FLUP	.99	10^{-2}	.999	.993
DLL	.99	10^{-2}	.999	.993
D-ORIS	.99	10^{-2}	.999	.993
D-OTIS	.99	10^{-2}	.999	.993
D-RVR	.99	10^{-2}	.999	.993
DSC	.99	10^{-2}	.999	.993
D-SIG	.99	10^{-2}	.999	.993
D-SIGMET	.99	10^{-2}	.999	.993
D-TAXI	.99	10^{-2}	.999	.993
DYNAV	.99	10^{-2}	.999	.993

Service	Continuity	Integrity	Availability (Provision)	Availability(Use)
FLIPCY	.99	10^{-2}	.999	.993
FLIPINT	.99	10^{-2}	.999	.993
ITP ACL	.99	10^{-2}	.999	.993
ITP SURV	.99	10^{-2}	.999	.993
M&S ACL	.99	10^{-2}	.999	.993
M&S SURV	.99	10^{-2}	.999	.993
PAIRAPP ACL	-	-	-	-
PAIRAPP SURV	-	-	-	-
PPD	.95	10^{-2}	.99	.99
SAP	.99	10^{-2}	.999	.993
SURV	.99	10^{-2}	.999	.993
TIS-B	.99	10^{-2}	.999	.993
URCO	.99	10^{-2}	.993	.993
WAKE	.99	10^{-2}	.993	.993

Table 4-1: Phase 1 Operational Assessment

ATC Service	Continuity	Integrity	Availability of Provision	Availability of Use
ACL	.9995	10^{-5}	.99995	.9999
ACM	.999	10^{-5}	.9995	.999
A-EXEC	.99999	10^{-7}	.9999995	.99999
AIRSEP	.9995	10^{-5}	.99995	.9999
AIRSEP SURV	.9995	10^{-5}	.99995	.9999
AMC	.995	10^{-3}	.999	.993
ARMAND	.999	10^{-5}	.9995	.999
C&P ACL	.999	10^{-5}	.9995	.999
C&P SURV	.999	10^{-5}	.9995	.999
COTRAC	.9995	10^{-5}	.99995	.9999
D-ALERT	.999	10^{-5}	.999	.999
D-ATIS	.999	10^{-5}	.9995	.999
DCL	.999	10^{-5}	.9995	.999
D-FLUP	.999	10^{-5}	.9995	.999
DLL	.999	10^{-5}	.9995	.999
D-ORIS	.999	10^{-5}	.9995	.999
D-OTIS	.999	10^{-5}	.9995	.999
D-RVR	.999	10^{-5}	.9995	.999
DSC	.999	10^{-5}	.9995	.999
D-SIG	.999	10^{-5}	.9995	.999
D-SIGMET	.999	10^{-5}	.9995	.999
D-TAXI	.999	10^{-5}	.9995	.999
DYNAV	.999	10^{-5}	.9995	.999
FLIPCY	.999	10^{-5}	.9995	.999
FLIPINT	.9995	10^{-5}	.99995	.9999
ITP ACL	.999	10^{-5}	.9995	.999
ITP SURV	.999	10^{-5}	.9995	.999
M&S ACL	.999	10^{-5}	.9995	.999
M&S SURV	.999	10^{-5}	.9995	.999
PAIRAPP ACL	.999	10^{-5}	.9995	.999
PAIRAPP SURV	.999	10^{-5}	.9995	.999
PPD	.999	10^{-3}	.999	.993
SAP	.999	10^{-5}	.9995	.999

ATC Service	Continuity	Integrity	Availability of Provision	Availability of Use
SURV	.9995	10^{-5}	.99995	.9999
TIS-B	-	-	-	-
URCO	.999	10^{-5}	.999	.999
WAKE	.999	10^{-5}	.999	.999

Table 4-2: Phase 2 Operational Assessment

4.2 Operational Safety Requirements

The hazard severity levels and resulting safety requirements for some of the Phase 1 ATS services are specified in [2]. These services are DLIC (DLL), ACM, ACL, AMC, DCL, DSC, D-ATIS, and FLIPCY. These Phase 1 safety requirements from [2] have extended to similar Phase 1 services not explicitly called out in [2].

This section specifies the Phase 2 ATS safety requirements. To determines these requirements, an operational safety assessment was conducted for each of the of eight ATS service categories. (See Section 2.2 for a listing of the service categories.) The most stringent safety requirements for any service within a service category determined the safety requirements for that category.

Note: The Operational Safety Assessment (OSA) was limited to hazards caused by the communication link; hazards outside of the communication portion of a given service, due to the Controller, and the Flight Crew were considered out-of-scope.

This section is organized as follows:

- The safety methodology used to perform the operational safety assessment is documented in Section 4.2.1.
- A summary of the operational safety hazards, severity, and safety objectives are provided in Section 4.2.2.
- The safety assessment for each ATS service is provided in Section 4.2.3.

4.2.1 Safety Methodology

The operational safety assessment identifies potential hazards that may arise during the use of the assessed service. The effects and consequences encountered as a result of such hazards are then established and evaluated.

The safety hazard effect was ranked using The FAA's Safety Management System Manual (SMS version 1.1) severity and likelihood definitions [14] and EUROCONTROL's Safety Regulatory Requirement (ESARR 4) Set 1 Severity Indicators [15].

Table 4-3 outlines the hazard effects and the standardised classification scheme used to describe the severity of the ATS services hazards.

Effect On ↓	Hazard Class				
	5 No Safety Effect (NO)	**4 Minor (MN)**	**3 Major (MJ)**	**2 Hazardous (HZ)**	**1 Catastrophic (CS)**
General		Does not significantly reduce system safety. Required actions are within operator's capabilities Includes:	Reduces the capability of the system or operators to cope with adverse operating conditions to the extent that:	Reduces the capability of the system of the operator's capability to cope with adverse conditions to the extents that:	Total loss of system control such that:
Air Traffic Control	Slight increase in ATC workload	Slight reduction in ATC capability, or significant increase in ATC workload	Reduction in separation as defined by a low/moderate severity operational error, or significant reduction in ATC capability	Reduction in separation as defined by a high severity operational error, or a total loss of ATC	Collisions with other aircraft, obstacles, or terrain
Flying Public	- No effect on flight crew - Has no safety effect - Inconvenience	- Slight increase in workload - Slight reduction in safety margin or functional capabilities - Minor illness or damage - Some physical discomfort	- Significant increase in flight crew workload - Significant reduction in safety margin or functional capability - Major illness, injury, or damage - Physical distress	- Large reduction in safety margin or functional capability - Serious or fatal injury to small number - Physical distress/excessive workload	Outcome would result in: - Hull loss - Multiple fatalities

Table 4-3: Description of Hazard Severity

Each class of hazard can be tolerated to a certain degree. For example, hazards of Class 5 can occur with more frequency than hazards of Class 4, due to the reduced severity of a Class 5 hazard. Since hazards can rarely be eliminated with complete certainty, even Class 1 hazards can be tolerated if they are extremely rare Safety Objectives have been defined to quantify and categorise the degree of tolerance in terms of a safety objective for each hazard class, as shown in Table 4-4.

Hazard Class	Safety Objective	Definition
5 No Safety Effect	Frequent	=>1 occurrence in 10^{-3} per flight hour
4 Minor	Probable	=<1 occurrence in 10^{-3} per flight hour
3 Major	Remote	=<1 occurrence in 10^{-5} per flight hour
2 Hazardous	Extremely Remote	=<1 occurrence in 10^{-7} per flight hour
1 Catastrophic	Extremely Improbable	=<1 occurrence in 10^{-9} per flight hour

Table 4-4: Safety Objective Definitions

The result of the safety assessment is a set of safety requirements. The requirements are procedures, equipment, and/or functional or environmental imperatives that must be implemented to reduce (i.e., mitigate) the probability of hazards in order to meet the associated Safety Objectives.

4.2.2 Summary of the ATS Services Operational Safety Assessments

At the highest level the ATS services operational safety hazards are 1) loss of service, and 2) hazardously misleading information. Loss of service is defined the lack of availability of a service when it is required. Hazardously misleading information consists of undetected corrupted messages, undetected mis-delivered messages, undetected late or missing messages and undetected out-of-sequence messages.

The safety analyses were based on the operational use of the services as described in Sections 2 and 3, in conjunction with the operational environment characteristics and conditions described in Sections 3.2.1 and 3.4.1. Results of these analyses may require updating as operating concepts, system requirements, and supported services evolve. The safety assessments were used to determine the operational performance requirements. Validated (complete and accurate) safety and performance requirements for communication services making use of the FRS (both air and ground) will need to occur prior to operational use. Table 4-5 and Table 4-6 and provides a summary of the hazard severity and consequent safety objective for the two high-level safety hazards for each of the eight ATS service categories in Phase 1 and Phase 2.

Note: Severity levels for DLL are not specified; but are levied on the service using the DLL information.

Service Category	Loss of Service		Hazardously Misleading Information	
	Severity	Safety Objective	Severity	Safety Objective
Data Communication Management Services (DCM)	5 (ACM)	Frequent	4 (ACM)	Probable
Clearance/ Instruction Services (CIS)	5	Frequent	3	Remote
Flight Information Services (FIS)	4	Probable	3	Remote
Advisory Services (AVS)	5	Frequent	4	Probable

Service Category	Loss of Service		Hazardously Misleading Information	
	Severity	Safety Objective	Severity	Safety Objective
Flight Position/ Intent/ Preferences Service (FPS)	5	Frequent	3	Remote
Emergency Information Services (EIS)	5	Frequent	3	Remote
Delegated Separation Services (DSS)	5	Frequent	3	Remote
Miscellaneous Services (MCS)	N/A		N/A	

Table 4-5: ATS Phase 1 Operational Safety Assessment Hazard Severity and Safety Objectives

Service Category	Loss of Service		Hazardously Misleading Information	
	Severity	Safety Objective	Severity	Safety Objective
Data Communications Management Services (DCM)	4 (ACM)	Probable	3 (ACM)	Remote
Clearance/ Instruction Services (CIS)	3	Remote	2	Extremely Remote
Flight Information Services (FIS)	4	Probable	2	Extremely Remote
Advisory Services (AVS)	3	Remote	2	Extremely Remote
Flight Position/ Intent/ Preferences Service (FPS)	3	Remote	2	Extremely Remote
Emergency Information Services (EIS)	4	Probable	3	Remote
Delegated Separation Services (DSS)	3	Remote	2	Extremely Remote
Miscellaneous Services (MCS)	1	Extremely Improbable	1	Extremely Improbable

Table 4-6: ATS Phase 2 Operational Safety Assessment Hazard Severity and Safety Objectives

4.2.3 Service Level Safety Assessment

Table 4-5 and Table 4-6 provide safety assessment for each ATS service for Phase 1 and Phase 2 respectively. The column headers are defined as follows:

- Service: The acronym for the ATS service.
- Integrity: The safety effect when an undetected error occurs.
- Continuity: The safety effect when communications fails once started.

- Availability of Provision: The safety effect when unable to communicate to all aircraft.
- Availability of Use: The safety effect when unable to communicate with one aircraft.

Service	Continuity	Integrity	Availability of Provision	Availability of Use
ACL	Major	No safety effect	No safety effect	No safety effect
ACM	Major	No safety effect	No safety effect	No safety effect
A-EXEC	-	-	-	-
AIRSEP	-	-	-	-
AIRSEP SURV	-	-	-	-
AMC	Minor	No safety effect	No safety effect	No safety effect
ARMAND	Major	No safety effect	No safety effect	No safety effect
C&P ACL	Major	No safety effect	No safety effect	No safety effect
C&P SURV	Hazardous	Minor	Minor	Minor
COTRAC	-	-	-	-
D-ALERT	Major	No safety effect	No safety effect	No safety effect
D-ATIS	Major	No safety effect	No safety effect	No safety effect
DCL	Major	No safety effect	No safety effect	No safety effect
D-FLUP	Minor	No safety effect	No safety effect	No safety effect
DLL	Major	No safety effect	No safety effect	No safety effect
D-ORIS	Major	No safety effect	No safety effect	No safety effect
D-OTIS	Minor	No safety effect	No safety effect	No safety effect
D-RVR	Minor	No safety effect	No safety effect	No safety effect
DSC	Major	No safety effect	No safety effect	No safety effect
D-SIG	Minor	No safety effect	No safety effect	No safety effect
D-SIGMET	Minor	No safety effect	No safety effect	No safety effect
D-TAXI	Minor	No safety effect	No safety effect	No safety effect
DYNAV	-	-	-	-
FLIPCY	Major	No safety effect	No safety effect	No safety effect
FLIPINT	Major	No safety effect	No safety effect	No safety effect
ITP ACL	Major	No safety effect	No safety effect	No safety effect
ITP SURV	Hazardous	Minor	Minor	Minor
M&S ACL	Major	No safety effect	No safety effect	No safety effect
M&S SURV	Hazardous	Minor	Minor	Minor
PAIRAPP ACL	-	-	-	-
PAIRAPP SURV	-	-	-	-
PPD	Major	No safety effect	No safety effect	No safety effect
SAP	Major	No safety effect	No safety effect	No safety effect
SURV (ATC)	Hazardous	Minor	Minor	Minor
TIS-B	Hazardous	Minor	Minor	Minor
URCO	-	-	-	-
WAKE	-	-	-	-

Table 4-7: Phase 1 Safety Assessment

Service	Continuity	Integrity	Availability of Provision	Availability of Use
ACL	Major	Hazardous	Hazardous	Major
ACM	Minor	Major	Major	Minor
A-EXEC	Catastrophic	Catastrophic	Catastrophic	Catastrophic
AIRSEP	Major	Hazardous	Hazardous	Major
AIRSEP SURV	Minor	Hazardous	Major	Minor
AMC	Minor	Major	Major	Minor
ARMAND	Minor	Minor	No safety effect	No safety effect
C&P ACL	Minor	Major	Major	Minor
C&P SURV	Major	Hazardous	Minor	Minor
COTRAC	Major	Hazardous	Hazardous	Major
D-ALERT	Major	Major	Minor	Minor
D-ATIS	Minor	Hazardous	Major	Minor
DCL	Major	Hazardous	Hazardous	Major
D-FLUP	Minor	Major	No safety effect	No safety effect
DLL	Minor	Hazardous	Major	Minor
D-ORIS	Minor	Hazardous	Major	Minor
D-OTIS	Minor	Hazardous	Major	Minor
D-RVR	Minor	Hazardous	Major	Minor
DSC	Major	Hazardous	Hazardous	Major
D-SIG	Minor	Hazardous	Minor	Minor
D-SIGMET	Minor	Hazardous	Minor	Minor
D-TAXI	Major	Hazardous	Hazardous	Major
DYNAV	No safety effect	Minor	No safety effect	No safety effect
FLIPCY	Major	Hazardous	Hazardous	Major
FLIPINT	Major	Hazardous	Hazardous	Major
ITP ACL	Minor	Major	Major	Minor
ITP SURV	Major	Hazardous	Minor	Minor
M&S ACL	Minor	Major	Major	Minor
M&S SURV	Major	Hazardous	Minor	Minor
PAIRAPP ACL	Major	Hazardous	Minor	Minor
PAIRAPP SURV	Hazardous	Hazardous	Minor	Minor
PPD	No safety effect	Minor	No safety effect	No safety effect
SAP	Minor	Major	Major	Minor
SURV (ATC)	Major	Hazardous	Major	Major
TIS-B	-	-	-	-
URCO	Major	Major	Minor	Minor
WAKE	Major	Hazardous	Minor	Minor

Table 4-8: Phase 2 Safety Assessment

4.3 Operational Information Security Requirements

This section specifies the operational information security requirements for the FRS following a logical, risk-based approach based against business goals.

This section contains a summary of the security analysis performed to derive security requirements, focusing on its most pertinent aspects. Complete details of the security analysis can be found in [11].

The security requirements developed apply to both voice and data when a new radio frequency (RF) link is used. It is expected that existing procedural means will continue to be used to help mitigate security concerns in existing voice links.

The security threat severity categories used have been aligned as far as possible with the safety hazard classes defined in Section 4.2.1. Use of identical definitions is not possible because security considers impacts other than safety impacts, for example financial impacts and impacts of business needs.

4.3.1 Business Goals for Information Security

The business goals for information security of the Future Communications Infrastructure are proposed as follows:

- **Safety:** The FCI must sufficiently mitigate attacks, which contribute to safety hazards. See Section 4.2.2 for a discussion of safety hazards.
- **Flight regularity:** The FCI must sufficiently mitigate attacks, which contribute to delays, diversions, or cancellations to flights.
- **Protection of business interests:** The FCI must sufficiently mitigate attacks which result in financial loss, reputation damage, disclosure of sensitive proprietary information, or disclosure of personal information.

The business goals must be met in a manner that is cost-effective in terms of total cost of ownership (including development costs, set-up costs, operating costs including communication overhead, and support costs) and without allowing security itself to reduce the safety of the system (for example by denying service to aircraft that are unable to authenticate their identity).

4.3.2 Process to Determine Security Requirements

Information security concerns the protection and defence of information and information systems. It aims to ensure an appropriate level of confidentiality, integrity, and availability of information in the face of deliberate attacks.

The evolutionary, attack-response nature of information security means that it is important to follow a defined process in order to develop security requirements so that the motivation for requirements is well understood and the analysis can be revisited and revised as attacks change. The process used to develop security requirements for the FRS is summarised in Figure 4-1.

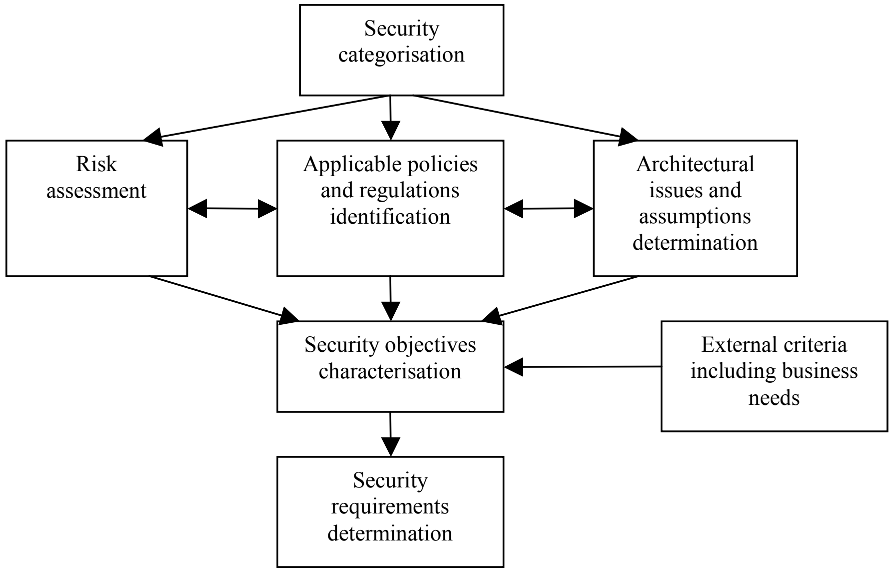

Figure 4-1: Information Security Requirement Process

The initial step, security categorisation, provides an initial assessment of the intrinsic sensitivity of the information being handled by the system and acts to focus efforts during the remainder of the process (e.g., evaluation of a threat severity).

Next, the risk assessment described in Section 4.3.3 analyses the threats to the system, their likelihood, and potential impact. Mitigating these threats to an acceptable level is the main driver during security requirement determination. Concurrently, applicable policies and regulations are identified, and architectural issues and assumptions are determined in Section 4.3.4. The focus is on areas that may need to be considered during security requirement determination.

Subsequently security objectives are characterised. These objectives summarise the results of the previous process steps and act as an opportunity to input external criteria such as business drivers into the process.

Finally the security requirements themselves are derived in Section 4.3.6, based primarily on the security objectives and the results of the risk assessment.

4.3.3 Risk assessment

Risk assessment is a crucial component of the information security requirements development process. Mitigating risk to an acceptable level is one of the main goals of the security requirements of a system. Mitigating risk to an acceptable level can only be achieved with an accurate understanding the system risk.

Risk assessment consists of two steps: threat identification, described in Section 4.3.3.1, and assessment of threat likelihood and threat severity, described in Section 4.3.3.2.

4.3.3.1 Threat Identification

The main threats to the FCI are listed in Table 4-9.

Threat Identifier	Threat Description
T.DENIAL	System resources may become exhausted due to system error, non-malicious user actions, or denial-of-service (DoS) attack.
T.DENIAL.FLOOD	An attacker floods a communications segment of the FCI with injected messages in order to reduce the availability of the FCI.
T.DENIAL.INJECT	An attacker injects malformed messages into a communications segment of the FCI in order to reduce the availability of the FCI.
T.DENIAL.INTERFERE	An attacker injects deliberate RF interference into an RF communication segment of the FCI in order to reduce the availability of the FCI.
T.ENTRY	An individual other than an authorised user may gain access via technical or non-technical attack for malicious purposes.
T.ENTRY.ALTER	An attacker delays/deletes/injects/modifies/re-directs/re-orders/replays or otherwise alters messages on a communications segment of the FCI in order to reduce the integrity of the FCI.
T.ENTRY. EAVESDROP	An attacker eavesdrops on messages on a communications segment of the FCI in order to reduce the confidentiality of the FCI.
T.ENTRY. IMPERSONATE	An attacker impersonates a user of the FCI in order to reduce the confidentiality or integrity of the FCI, or simply to gain free use of the FCI.

Table 4-9: FCI High-Level Threats

4.3.3.2 Threat Likelihood and Threat Severity

An initial assessment of threat likelihood and threat severity is provided in Table 4-10. The assessment assumes that the FCI contains no specific security controls or intrinsic security mitigations (such as the inherent mitigation of deliberate RF interference by certain spread spectrum radio systems).

Threat likelihood is ranked as “unlikely”, “likely”, or “highly likely” based on its potential for realisation. Two factors are used to determine the threat likelihood:

- **Motivation:** A ranking of how strong the motivation is to realise the threat. A value in the range 1-3 is assigned to motivation, with 3 representing strong motivation and 1 representing weak motivation.
- **Required capabilities:** A ranking of how much financial and technical capability is required to realise the threat. A value in the range 1-3 is assigned to required capabilities, with 3 representing a low requirement, and 1 representing a high requirement.

Threat likelihood values are determined by multiplying the motivation and required capabilities values – a result of 1 to 3 corresponds to “unlikely”, 4 to 6 corresponds to “likely”, and 7 to 9 corresponds to “highly likely”.

Threat severity is ranked based on the potential impact of the threat if it is realised, using the following categories:

- **None:** There is no perceivable impact on safety, flight regularity, or business interests.
- **Low:** There is a limited adverse effect on safety, flight regularity, or business interests.
- **Medium:** There is a serious adverse effect on safety, flight regularity, or business interests.
- **High–Severe:** There is a severe adverse effect on safety, flight regularity, or business interests.
- **High–Catastrophic:** There is a catastrophic effect on safety, flight regularity, or business interests.

To calculate severity, potential impacts on safety, flight regularity, and business needs are considered, and a value in the range 1-5 assigned to each, with 1 being the most serious impact and 5 being the least serious impact. Threat severity is then determined based on the maximum of the three values assigned, with a maximum value of 1 corresponding to "high – catastrophic", 2 corresponding to "high – severe", etc.

The information security assessment in Table 4-10 is necessarily only a preliminary assessment at this early stage in the development of the FCI. The assessment will need to be regularly revisited and revised in order to ensure that it remains up-to-date with attack innovations and development decisions.

Threat Identifier	Likelihood			Severity			
	Motivation	**Required Capabilities**	**Overall**	**Safety**	**Flight Regularity**	**Business Needs**	**Overall**
T.DENIAL							
T.DENIAL.FLOOD	3	2	Likely	2	3	3	High - Severe
T.DENIAL.INJECT	3	2	Likely	2	3	3	High - Severe
T.DENIAL. INTERFERE	3	3	Highly likely	2	3	3	High - Severe
T.ENTRY							
T.ENTRY.ALTER	3	2	Likely	1	4	2	High - Catastro phic
T.ENTRY. EAVESDROP	3	3	Highly likely	5	5	2	High - Severe
T.ENTRY. IMPERSONATE	3	2	Likely	1	4	2	High - Catastro phic
Motivation Required capabilities	1 = weak, 3 = strong 1 = high, 3 = low			Severity	1 = most serious 5 = least serious		

Table 4-10: Threat Likelihood and Severity

4.3.4 Service Level Threat Severity Assessment

Table 4-11 and Table 4-12 provide the information security service level threat severity assessment for ATS and AOC services, respectively. The column headers are defined as follows:

- Service: The acronym for the service name.
- Confidentiality: This column represents the relative operational impact of violation of confidentiality.
- Integrity: This column represents the relative operational impact of corruption of the integrity.
- Availability: This column represents the relative operational impact of the loss of use/provision of the service.

The threat severity categories (e.g., high and medium) are defined in Section 4.3.3.2.

Service	Confidentiality	Integrity	Availability
ACL	Low	High-Severe	High-Severe
ACM	None	High-Severe	High-Severe
A-EXEC	Low	High-Catastrophic	High-Catastrophic
AIRSEP	Low	High-Severe	High-Severe
AIRSEP SURV	Low	High-Severe	High-Severe
AMC	None	Low	Medium
ARMAND	Low	Low	Low
C&P ACL	Low	High-Severe	High-Severe
C&P SURV	Low	High-Severe	Medium
COTRAC	Low	High-Severe	High-Severe
D-ALERT	Medium	High-Severe	High-Severe
D-ATIS	None	High-Severe	Medium
DCL	None	High-Severe	High-Severe
D-FLUP	None	Medium	Low
DLL	None	High-Severe	High-Severe
D-ORIS	None	Medium	Low
D-OTIS	None	High-Severe	Medium
D-RVR	None	High-Severe	Low
DSC	Low	High-Severe	Medium
D-SIG	None	Medium	Low
D-SIGMET	None	High-Severe	Medium
D-TAXI	Low	High-Severe	Medium
DYNAV	Low	High-Severe	Medium
FLIPCY	Low	High-Severe	Medium
FLIPINT	Low	High-Severe	High-Severe
ITP ACL	Low	High-Severe	High-Severe
ITP SURV	Low	High-Severe	Medium
M&S ACL	Low	High-Severe	High-Severe
M&S SURV	Low	High-Severe	Medium
PAIRAPP ACL	Low	High-Severe	High-Severe
PAIRAPP SURV	Low	High-Severe	Medium
PPD	Low	Low	Low
SAP	Low	Medium	Low
SURV	Low	High-Severe	Medium
TIS-B	Low	High-Severe	Medium
URCO	None	Medium	Medium
WAKE	None	High-Severe	High-Severe

Table 4-11: Information Security Threat Severity for ATS Services

Information Type	Confidentiality	Integrity	Availability
AOCDLL	None	High-Severe	High
CABINLOG	Low	Low	Low
ENGINE	Low	Medium	Medium
FLTLOG	Medium	Low	Low
FLTPLAN	Low	High-Severe	High
FLTSTAT	Medium	Low	Low
FREETXT	Medium	Low	Low
FUEL	Low	Low	Low
GATES	Low	Low	Low
LOADSHT	Medium	High-Severe	High
MAINTPR	Medium	Medium	Low
MAINTRT	Medium	Medium	Low
NOTAM	None	Medium	Medium
OOOI	Low	Low	Low
POSRPT	Low	Medium	Medium
SWLOAD	Low	Low	Low
TECHLOG	Medium	Medium	Medium
UPLIB	Medium	High-Severe	Medium
WXGRAPH	Low	Medium	Medium
WXRT	None	Medium	Medium
WXTEXT	Low	Medium	Low

Table 4-12: Information Security Threat Severity for AOC Services

4.3.5 Architectural Issues and Assumptions

There are a wide variety of security controls or countermeasures and it is necessary to consider various architectural issues in order to determine which controls should be used to protect the FCI.

Controls based on cryptography and encryption can be applied at a variety of protocol layers. One important question is which layer or layers of the FCI should include cryptographic protection. The answer to this question will clarify the extent to which controls impinge on the specification of the FRS.

In addition, procedural controls such as voice read-back and waveform controls such as frequency hopping can be used to mitigate certain threats. Redundancy can be built into the provision of any part of the FCI, through duplication of elements such as radios, and alternate network paths. A firewall can be placed at any network interconnection, and apply rules for packet filtering based on parameters such as originator and destination address.

The properties of these controls are summarised in Table 4-13.

	Involves	Example	Good for
Procedural controls	Human users	Voice readback	T.ENTRY.ALTER
End-to-end cryptographic protection	End systems	Aeronautical Telecommunications Network (ATN) Security, S/MIME, SSL/TLS	T.ENTRY.ALTER T.ENTRY.EAVESDROP T.ENTRY.IMPERSONATE
Network level cryptographic protection	Boundary Intermediate Systems (BIS)	IPSec	T.ENTRY.ALTER T.ENTRY.EAVESDROP T.ENTRY.IMPERSONATE
Link level cryptographic protection	Radio, logical characteristics	Wireless LAN, GSM security measures	T.DENIAL.FLOOD T.DENIAL.INJECT T.ENTRY.ALTER T.ENTRY.EAVESDROP T.ENTRY.IMPERSONATE
Waveform controls	Radio, RF characteristics	Spread spectrum	T.DENIAL.FLOOD T.DENIAL.INTERFERE
Redundancy	Second radio system (same or different technology)	VHF voice alternate radio site (ground), spare channels	T.DENIAL.FLOOD T.DENIAL.INTERFERE
Firewall	Routers	COTS firewall products	T.DENIAL.FLOOD T.DENIAL.INJECT

Table 4-13: Properties of Security Controls

The conclusions of the architectural discussion are:

- Cryptographic protection appears to be the preferred approach to mitigate T.ENTRY.ALTER, T.ENTRY.EAVESDROP, and T.ENTRY.IMPERSONATE.
- Cryptographic protection at the link layer, network layer, or application layer can be used to mitigate T.ENTRY.ALTER, and T.ENTRY.IMPERSONATE. There are trade-offs involved in deciding which protocol layer to protect. For example, application layer protection may be preferred from a security perspective since it secures the packet end-to-end. But link layer protection may be preferred from a cost perspective since a single secure channel can be used to protect a large number of services.
- Cryptographic protection at the link layer, network layer, or application layer can also be used to mitigate T.ENTRY.EAVESDROP. However since only a small number of services require mitigation of T.ENTRY.EAVESDROP and encryption could affect the safety of ATS services, it is expected that end-to-end cryptographic protection will be used in this case.
- One control that mitigates T.DENIAL.INJECT is link level cryptographic protection. This would impact the FRS specification. Use of a firewall to

selectively filter received data is an alternative, which would not impact the FRS specification.

- A system configuration, which involves radio set and channel redundancy may be a cost effective way to mitigate T.DENIAL.INTERFERE and T.DENIAL.FLOOD, since such redundancy is already expected to be required to address safety issues associated with equipment failure.

4.3.6 Information Security Requirements

This section specifies the information security requirements developed based on the analysis that has been performed. First, security requirements for the FCI are developed, and then security requirements for the FRS are extrapolated based on the FCI requirements.

The FCI security requirements are specified in Table 4-14.

Requirement Id	Requirement	Associated Threats
R.FCI-SEC.1a	The FCI shall support reliability and robustness to mitigate denial of service attacks when providing services with “high – severe” or “high – catastrophic” availability ranking.	T.DENIAL.FLOOD T.DENIAL.INJECT T.DENIAL.INTERFERE
R.FCI-SEC.1b	The FCI should support reliability and robustness to mitigate denial of service attacks when providing services with “medium” availability ranking.	T.DENIAL.FLOOD T.DENIAL.INJECT T.DENIAL.INTERFERE
R.FCI-SEC.2a	The FCI shall support message authentication and integrity to prevent message alteration attacks when providing services with “high – severe” or “high – catastrophic” integrity ranking.	T.DENIAL.INJECT T.ENTRY.ALTER T.ENTRY.IMPERSONATE
R.FCI-SEC.2b	The FCI should support message authentication and integrity to prevent message alteration attacks when providing services with “medium” integrity ranking.	T.DENIAL.INJECT T.ENTRY.ALTER T.ENTRY.IMPERSONATE
R.FCI-SEC.3a	The FCI shall support encryption to mitigate eavesdropping when providing services with “high – severe” confidentiality ranking.	T.ENTRY.EAVESDROP
R.FCI-SEC3b	The FCI should support encryption to mitigate eavesdropping when providing services with “medium” confidentiality ranking.	T.ENTRY.EAVESDROP
R.FCI-SEC.4a	The FCI shall support entity authentication to mitigate impersonation attacks when providing services with “high – severe” or “high – catastrophic” integrity ranking.	T.ENTRY.ALTER T.ENTRY.IMPERSONATE
R.FCI-SEC.4b	The FCI should support entity authentication to mitigate impersonation attacks when providing services with “medium” integrity ranking.	T.ENTRY.ALTER T.ENTRY.IMPERSONATE
R.FCI-SEC.5	The operation of the FCI security function shall not diminish the ability of the FCI to operate safely and effectively.	

Table 4-14: FCI Information Security Requirements

Specific FRS information security requirements have derived from the FCI information security requirements are specified in Table 4-15.

Requirement Id	Requirement	Associated FCI Requirements
R.FRS-SEC.1a	The FRS shall provide a measure of resistance against deliberate insertion of RF interference when providing services with “high – severe” or “high – catastrophic” availability ranking.	R.FCI-SEC.1
R.FRS-SEC.1b	The FRS should provide a measure of resistance against deliberate insertion of RF interference when providing services with “medium” availability ranking.	R.FCI-SEC.1
R.FRS-SEC.2a	The FRS shall support message authentication and integrity as an option to prevent message alteration attacks when providing services with “high – severe” or “high – catastrophic” integrity ranking.	R.FCI-SEC.2 R.FCI-SEC.5
R.FRS-SEC.2b	The FRS should support message authentication and integrity as an option to prevent message alteration attacks when providing services with “medium” integrity ranking.	R.FCI-SEC.2 R.FCI-SEC.5
R.FRS-SEC.3a	The FRS shall support entity authentication as an option to mitigate impersonation attacks when providing services with “high – severe” or “high – catastrophic” integrity ranking.	R.FCI-SEC.4 R.FCI-SEC.5
R.FRS-SEC.3b	The FRS should support entity authentication as an option to mitigate impersonation attacks when providing services with “medium” integrity ranking.	R.FCI-SEC.4 R.FCI-SEC.5

Table 4-15: FRS Information Security Requirements

Note: The A-EXEC service raises new security problems because it is the first communications service introducing a "high - catastrophic" confidentiality, integrity, or availability ranking. Providing sufficient security for this service requires further research.

5 PERFORMANCE REQUIREMENTS

An Operational Performance Assessment (OPA) is normally conducted to determine the performance a system or service must achieve. OPA results typically include determination of the availability, integrity, and transaction times. These performance requirements are driven both by operational needs and safety requirements. In addition to the OPA, other assessments (e.g., information security) may be conducted to determine other communication performance requirements.

Performance assessments start with an end-to-end context and allocate performance requirements to humans, systems and or subsystems. The OPA begins with Required Communication Performance (RCP) and allocates these requirements to humans and technical components (e.g., equipment). The term Required Communication Technical Performance (RCTP) refers to the allocation to the technical components.

This section provides the technical communication performance requirements for the COCR voice and data communication services. The COCR technical communication performance requirements are based on a combination of prior safety work, subject matter expertise, and performance assessments.

Note: Although both voice and data requirements are provided, allocated FRS requirements are only developed for data communications.

The communication loading analysis in Section 6 uses allocated FRS performance requirements in the Section to estimate FRS capacity requirements. Although the loading analysis evaluates a reasonable worst case scenario for service utilization, there is not an instance of use for every service in every domain listed herein.

5.1 Voice Requirements

Table 5-1 and Table 5-2 provide the voice performance requirements for ATS and AOC communication, respectively. Performance values are based on information in [53], [44] and input from subject matter experts. The quality of the voice must be sufficient to meet the operational requirement in the airspace where it is used. Quality includes user acceptability and intelligibility.

Service Type	**Party-line**									**Broadcast**
Domain	**APT**		**TMA**		**ENR**		**ORP**		**AOA**	**ALL**
Density	**HD**	**LD**	**HD**	**HD**	**HD**	**LD**	**HD**	**LD**		**ALL**
Call Establishment Delay	100 ms	100 ms	100 ms	100 ms	100ms	100 ms	100 ms	20 s	100 ms	20 s
Voice Latency	130 ms	130 ms	130 ms	130ms	130 ms	130 ms	130ms	485 ms	130 ms	485 ms
A_P	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.999
A_U	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.998

Table 5-1: ATS Voice Performance Requirements

Service Type	Selective Addressed	Party-line/Broadcast
Domain	**ALL**	**ALL**
Density	**ALL**	**ALL**
Call Establishment Delay	20 s	20 s
Voice Latency	485 ms	485 ms
A_P	0.999	0.999
A_U	0.998	0.998

Table 5-2: AOC Voice Performance Requirements

5.2 Data Requirements

This section provides the overall RCTP requirements for ATS and AOC data communication services and the allocated FRS technical performance requirements.

5.2.1 RCTP Requirements

This section summarizes the requirement methodologies, provides technical data communication requirements for Phase 1 and Phase 2 ATS and AOC services, and provides supporting requirement information.

5.2.1.1 RCTP Methodology

5.2.1.1.1 Phase 1 ATS Service Requirement Methodology

The Phase 1 ATS performance requirements are primarily drawn from previous service performance assessments (i.e., [2] and [55]). For services not covered in previous assessments, performance requirements are based on:

- Performance requirements for comparable services
- Subject matter expertise

5.2.1.1.2 Phase 2 ATS Service Requirement Methodology

An OPA was performed on the communication portion of each of the Phase 2 ATS services described in Section 2.2. The scope of the OPA does not include performance requirements for airborne and ground automation functions such as route generation, depiction, loading, conflict and out-of-conformance detection, and the generation of alerts.

To determine the communication performance requirements the more stringent of the safety objectives and operational requirements for each parameter was used. The operational requirements are driven by the type of exchange (e.g., trajectory change, general information) and the domain in which the service was offered. The safety objectives for the Phase 2 ATS service categories are listed in Table 4-6. The OPA results are provided in Table 5-5.

The following comments apply to the Phase 2 ATS OPA.

- The SURV, TIS-B and WAKE requirements are based on [5], [56], and [57].
- The integrity requirements are determined from the hazard severity classification contained in the *Hazardously Misleading Information* column for each of the ATS services categories as shown in Table 4-6.
- The availability of provision (A_P) requirements are determined from the hazard severity classification contained in the *Loss of Service* column for each of the ATS services categories as shown in Table 4-6.

5.2.1.1.3 AOC Service Requirement Methodology

The AOC service requirements are based on a high level performance assessment and subject matter expertise.

5.2.1.2 RCTP Performance Values

Table 5-4, Table 5-5 and Table 5-6 provide performance requirements for data communications.

Service	Update Interval (secs) 95% Confidence Level Phase 1					Update Interval (secs) 95% Confidence Level Phase 2				
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA
C&P SURV	-	3	3	3	-	-	3	3	3	-
ITP SURV	-	3	3	3	-	-	3	3	3	-
M&S SURV	-	3	3	3	-	-	3	3	3	-
PAIRAPP SURV			-	-	-	2*	2*	-	-	-
AIRSEP SURV	-	-	-	-		-	-	-	-	5*
SURV (ATC)	2	5	10	10		2	5	5	5	5**
TIS-B	2	5	10	10	-		-	-	-	-
WAKE	2	5	10	-	-	2	5	5	-	

Table 5-3: ATS Broadcast Service Update Intervals

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95}- 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UIT}	I_{UCT}	A_P	A_U
ACL	10.0	10.0	10.0	75.0	-	8.0	8.0	8.0	60.0	-	0.995[3]	1.0E-5	0.999	0.993[4]
ACM	10.0	10.0	10.0	75.0	-	8.0	8.0	8.0	60.0	-	0.995	1.0E-5	0.999	0.993
A-EXEC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AIRSEP	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AIRSEP SURV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AMC	10.0	10.0	10.0	-	-	8.0	8.0	8.0	-	-	0.995	1.0E-3	0.999	0.993
ARMAND	-	-	30.0	-	-	-	-	20.0	-	-	0.995	1.0E-5	0.999	0.993
C&P ACL	-	20.0	20.0	75.0	-	-	12.0	12.0	60.0	-	0.995	1.0E-5	0.999	0.993
C&P SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
COTRAC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D-ALERT	20.0	20.0	20.0	75.0	-	12.0	12.0	12.0	60.0	-	0.995	1.0E-5	0.999	0.993
D-ATIS	15.0	15.0	15.0	90.0	-	10.0	10.0	10.0	60.0	-	0.995	1.0E-5	0.999	0.993
DCL	30.0	-	-	-	-	20.0	-	-	-	-	0.995	1.0E-5	0.999	0.993
D-FLUP	30.0	-	-	-	-	20.0	-	-	-	-	0.995	1.0E-3	0.999	0.993
DLL	20.0	20.0	20.0	100.0	-	12.0	12.0	12.0	60.0	-	0.995	1.0E-5	0.999	0.993
D-ORIS	-	15.0	15.0	90.0	-	-	10.0	10.0	60.0	-	0.995	1.0E-5	0.999	0.993
D-OTIS	15.0	15.0	15.0	90.0	-	10.0	10.0	10.0	60.0	-	0.995	1.0E-5	0.999	0.993
D-RVR	15.0	15.0	15.0	90.0	-	10.0	10.0	10.0	60.0	-	0.995	1.0E-5	0.999	0.993
DSC	-	-	60.0	72.0	-	-	-	50.0	60.0	-	0.995	1.0E-5	0.999	0.993
D-SIG	30.0	30.0	-	-	-	20.0	20.0	-	-	-	0.995	1.0E-5	0.999	0.993
D-SIGMET	15.0	15.0	15.0	90.0	-	10.0	10.0	10.0	60.0	-	0.995	1.0E-5	0.999	0.993
D-TAXI	20.0	20.0	-	-	-	12.0	12.0	-	-	-	0.995	1.0E-5	0.999	0.993
DYNAV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FLIPCY	40.0	40.0	40.0	80.0	-	30.0	30.0	30.0	60.0	-	0.995	1.0E-5	0.999	0.993
FLIPINT	40.0	40.0	40.0	80.0	-	30.0	30.0	30.0	60.0	-	0.995	1.0E-5	0.999	0.993
ITP ACL	-	-	-	75.0	-	-	-	-	60.0	-	0.995	1.0E-5	0.999	0.993
ITP SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
M&S ACL	-	20.0	20.0	-	-	-	12.0	12.0	-	-	0.995	1.0E-5	0.999	0.993
M&S SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
PAIRAPP ACL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAIRAPP SURV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PPD	40.0	40.0	40.0	80.0	-	30.0	30.0	30.0	60.0	-	0.995	1.0E-5	0.999	0.993
SAP	-	15.0	15.0	-	-	-	10.0	10.0	-	-	0.995	1.0E-5	0.999	0.993
SURV (ATC)	4.0	10.0	20.0	20.0	-	1.2	2.0	2.0	2.0	-	0.99995	1.0E-7	0.999995	0.9999
TIS-B	4.0	10.0	20.0	20.0	-	1.2	2.0	2.0	2.0	-	0.99995	1.0E-7	0.999995	0.9999
URCO	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAKE	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5-4: Phase 1 ATS RCTP Performance Requirements

[3] For the ORP domain, the continuity requirement is 0.999.
[4] For the ORP domain, the availability of use requirement is 0.999.

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95}- 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UIT}	I_{UCT}	A_P	A_U
ACL	6.25	6.25	6.25	20.0	6.25	3.0	3.0	3.0	12.5	3.0	0.9995	1.0E-7	0.99999	0.999
ACM	6.25	6.25	6.25	20.0	6.25	3.0	3.0	3.0	12.5	3.0	0.9995	1.0E-7	0.99999	0.999
A-EXEC	-	2.0	2.0	2.0	-	-	1.65	1.65	-	-	0.9999999	1.0E-9	0.999999999	0.9999999
AIRSEP	-	-	-	-	9.75	-	-	-	-	5.0	0.9995	1.0E-7	0.99999	0.999
AIRSEP SURV	-	-	-	-	10.0	-	-	-	-	2.0	0.9995	1.0E-7	0.99999	0.999
AMC	10.0	10.0	10.0	-	30.0	8.0	8.0	8.0	-	20.0	0.995	1.0E-3	0.999	0.993
ARMAND	-	-	17.0	-	-	-	-	10.0	-	-	0.995	1.0E-3	0.999	0.99
C&P ACL	-	9.75	9.75	20.0	-	-	5.0	5.0	12.5	-	0.9995	1.0E-7	0.99999	0.999
C&P SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
COTRAC	-	9.75	9.75	20.0	9.75	-	5.0	5.0	12.5	5.0	0.9995	1.0E-7	0.99999	0.999
D-ALERT	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-5	0.99999	0.999
D-ATIS	9.75	9.75	9.75	30.0	30.0	5.0	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
DCL	30.0	-	-	-	-	20.0	-	-	-	-	0.9995	1.0E-7	0.99999	0.999
D-FLUP	9.75	9.75	17.0	30.0	30.0	5.0	5.0	10.0	20.0	20.0	0.995	1.0E-3	0.999	0.99
DLL	6.25	9.75	17.0	30.0	30.0	3.0	5.0	10.0	20.0	20.0	0.9995	1.0E-7	0.99999	0.999
D-ORIS	-	9.75	9.75	30.0	30.0	-	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
D-OTIS	9.75	9.75	9.75	30.0	30.0	5.0	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
D-RVR	6.25	6.25	9.75	30.0	30.0	3.0	3.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
DSC	-	-	30.0	20.0	30.0	-	-	20.0	50.0	20.0	0.9995	1.0E-7	0.99999	0.999
D-SIG	17.0	17.0	-	-	-	10.0	10.0	-	-	-	0.995	1.0E-7	0.999	0.99
D-SIGMET	9.75	9.75	9.75	30.0	30.0	5.0	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
D-TAXI	9.75	9.75	-	-	-	5.0	5.0	-	-	-	0.9995	1.0E-7	0.99999	0.999
DYNAV	-	-	17.0	30.0	-	-	-	10.0	20.0	-	0.995	1.0E-3	0.999	0.99
FLIPCY	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-7	0.99999	0.999
FLIPINT	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-7	0.99999	0.999
ITP ACL	-	9.75	9.75	20.0	-	-	5.0	5.0	12.5	-	0.9995	1.0E-7	0.99999	0.999
ITP SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
M&S ACL	-	9.75	9.75	20.0	-	-	5.0	5.0	12.5	-	0.9995	1.0E-7	0.99999	0.999
M&S SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
PAIRAPP ACL	-	9.75	-	-	-	-	5.0	5.0	-	-	0.9995	1.0E-7	0.99999	0.999
PAIRAPP SURV	4.0	4.0	-	-	-	1.2	1.2	-	-	-	0.99995	1.0E-7	0.999	0.999
PPD	17.0	17.0	17.0	30.0	30.0	10.0	10.0	10.0	20.0	10.0	0.995	1.0E-3	0.999	0.99
SAP	-	9.75	9.75	-	-	-	5.0	5.0	-	-	0.9995	1.0E-7	0.99999	0.999
SURV (ATC)	4.0	10.0	10.0	10.0	10.0	1.2	2.0	2.0	2.0	2.0	0.99995	1.0E-7	0.999995	0.9999
TIS-B	-	-	-	-	-	-	-	-	-	-	-	-	-	-
URCO	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-5	0.99999	0.999
WAKE	4.0	10.0	10.0	-	-	1.2	2.0	2.0	-	-	0.9995	1.0E-7	0.999	0.999

Table 5-5: Phase 2 ATS RCTP Performance Requirements (ATS)

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95}- 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UIT}	I_{UCT}	A_P	A_U
AOCDLL						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
CABINLOG						60.0	-	-	-	-		1.0E-3	0.999	0.99
ENGINE						60.0	60.0	60.0	120.0	120.0		1.0E-4	0.999	0.99
FLTLOG						60.0	-	-	-	-		1.0E-3	0.999	0.99
FLTPLAN						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
FLTSTAT						30.0	30.0	30.0	60.0	60.0		1.0E-3	0.999	0.99
FREETXT						60.0	60.0	60.0	120.0	120.0		1.0E-3	0.999	0.99
FUEL						60.0	60.0	60.0	120.0	120.0		1.0E-3	0.999	0.99
GATES						30.0	30.0	30.0	60.0	60.0		1.0E-3	0.999	0.99
LOADSHT						30.0	30.0	-	-	-		1.0E-7	0.999	0.99
MAINTPR	Not Available					30.0	30.0	30.0	60.0	60.0	Not Available	1.0E-4	0.999	0.99
MAINTRT						60.0	60.0	60.0	120.0	120.0		1.0E-4	0.999	0.99
NOTAM						60.0	60.0	60.0	120.0	120.0		1.0E-7	0.999	0.99
OOOI						30.0	-	-	-	-		1.0E-3	0.999	0.99
POSRPT						60.0	60.0	60.0	120.0	120.0		1.0E-4	0.999	0.99
SWLOAD						60.0	60.0	60.0	120.0	120.0		1.0E-9	0.999	0.99
TECHLOG						60.0	-	-	-	-		1.0E-4	0.999	0.99
UPLIB						60.0	60.0	60.0	120.0	120.0		1.0E-7	0.999	0.99
WXGRAPH						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
WXRT						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
WXTEXT						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99

Table 5-6: AOC RCTP Performance Requirements

5.2.1.3 RCTP Supporting Information

5.2.1.3.1 One-Way and Two-Way Transaction Requirements

OPA results only provide two-way technical transaction and expiration times that start with an initial message and end with an associated closing operational response. Not all operational responses are closing responses, e.g., standby does constitute a closure response. Thus, these assessments are necessarily limited to two-way dialogs.

For a one-way service (e.g., AMC, FLIPINT report), the service latencies should be specified. In addition, the use of expiration time and continuity parameters for one-way services can be used to provide another constraint on timing performance (in addition to a 95^{th} percentile latency).

The RCTP tables provide one-way latencies and expiration times. For two-way services, the one-way latencies and expiration timers are one-half the two-way times. For these services, the performance requirements are met when the two-way times are met. For example, the Phase 1 ACL service has a latency of 8 seconds. If the two-way 95^{th} percentile transaction time is 16 seconds or less, the OPA performance requirement is met. For example, initiating message has a transit delay of 10 seconds and the closure response has a transit delay of 6 seconds, the ACL technical transaction time requirement is met.

5.2.1.3.2 Broadcast Requirements

Broadcast services have performance parameter definitions that are analogous but not identical to two-way operational exchanges. The following performance parameter definitions and assumptions apply to the SURV, TIS-B and WAKE services in Table 5-3 through Table 5-6.

- **Update Interval:** This is the time interval within which there is a percentile probability of receiving at least one report update.
- **Expiration Time:** The expiration time is the maximum time between updates beyond which a service interruption is declared. It has been set as twice the update interval shown in Table 5-3.
- **Latency:** For SURV, one-way latency is the time taken from the reception of the navigational signal (e.g., GNSS) by an aircraft antenna to the output of positional information at a Controller position or on an aircraft CDTI. It includes the reception of the raw navigational signal, processing of it to determine position, transmission of the position information, reception, and processing by the surveillance processing system on the ground or in another aircraft. For TIS-B, it is the time taken from the input to the surveillance source to the display on an aircraft CDTI. For WAKE, it is the time taken from sensor(s) output to delivery to the WAKE information processing system.
- **Continuity:** This is the probability that a system will continue to perform its required function without unscheduled interruption, assuming that the system is available when the procedure is initiated.

5.2.2 FRS Requirements

The FRS data performance requirements are allocated based on the overall end-to-end technical data communication requirements.

This section describes the following:

- FRS Boundary Point Description – the boundary point used for the allocation of data performance requirements
- Allocation methodology and assumptions
- FRS Allocated Performance Values

5.2.2.1 FRS Boundary Point Description

ATM services are described in an operational context and requirements apply to the service as a whole including communication systems, automation systems, procedures and human participation. Ground end points (Controllers, automation systems) connect to airborne end points (Flight Crew, flight automation systems) via a set of one or more networks and/or communication systems. The FRS is a system in the end-to-end communication chain.

The FRS Boundary Point can be described in terms of both physical and logical perspectives. There are some physical aspects that remain constant regardless of the technology selection or implementation approach. For example, there will be FRS communication equipment in the aircraft and on the ground. Other physical aspects are very technology specific, e.g., the immediate physical interface for the FRS equipment (examples include T1, RS-232, and proprietary hardware interfaces). From a logical point of view, the FRS boundary can be illuminated by describing functions that lie on either side of the interface.

In order to allocate performance requirements to the FRS, one must first define the interface boundary for the FRS.

5.2.2.1.1 Addressed FRS Boundary Point Description

Since communication networks typically involve multiple communication layers, the FRS boundary can be described within the context of a communication protocol stack.

The COCR has defined the logical interface to the FRS subnetwork at the boundary between the internetworking and intranetworking layers of the reference protocol stack. While the COCR does not specify a required reference protocol stack, Figure 5-1 provides an illustration showing the boundary point within several example protocol stacks.

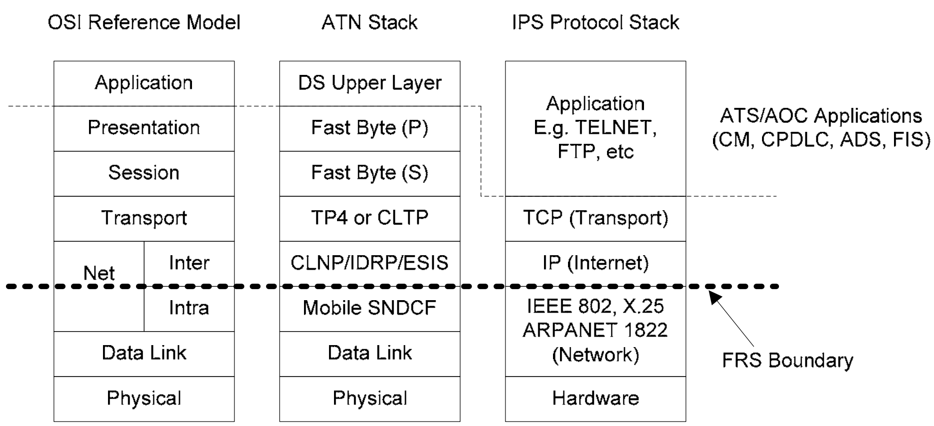

Figure 5-1: FRS Boundary Point Examples

From a functional point of view, the FRS addressed performance requirements span the following functional blocks: subnetwork interface function, subnetwork layer, data link layer, ground and airborne FRS radio units, antennas and RF media.

From a physical point of view, the logical FRS boundary points will likely be located in the Air-Ground Router (a ground unit) and Airborne Router. Since a ground router might not be co-located with the FRS radio equipment, it is important to note that performance contributions associated with such a remote connection (e.g., delays, availability, integrity) are specifically excluded from the FRS allocated performance requirements.

5.2.2.1.2 Broadcast FRS Boundary Point Description

For services that can be implemented without a network protocol stack (e.g., TIS-B, WAKE, SURV), the boundary point is defined at the mobile communication equipment interface, e.g., radio interface.

5.2.2.2 FRS Allocation Assumptions

Typically, the allocation of performance to communication segments (or systems) is based, at least in part, on the ability of the particular segment to meet the requirement. Most safety and performance work has allocated requirements to the ground and airborne segments with the boundary point at the aircraft antenna. However, this segment boundary does not align with the boundaries of interest for the FRS. Part of the FRS system lies within the ground segment and the other part within the airborne segment. The FRS allocation is made using the end-to-end technical performance numbers while considering the ATS/Airborne segment allocations made in prior safety work.

The allocation process used for air-air and AOC services is the same as that used for ATS services in that the ability of each component, segment or system to meet the allocated requirement is considered.

The following subsections provide detailed information on the assumptions and rationale used for allocating latency, integrity, and availability requirements to the FRS.

5.2.2.2.1 Latency

The RCTP one-way latency requirement is specified in terms of a probability, e.g., a 95% percentile delay. As defined in [13], a statistical analysis should be conducted in order to properly allocate the performance parameters between system segments and/or components. Much of the prior allocation work has used an algebraic allocation methodology, possibly because the statistical distribution of events was not well characterised.

If statistical allocations were made instead of algebraic ones, the 95% allocation for each subsystem/component would be larger (assuming use of any one of a number of common distributions, e.g., normal, exponential, lognormal, Poisson, which might be applied to message delays for typical systems). Thus, the algebraic allocations are more restrictive than a statistical allocation method. This more restrictive method can still result in ‘valid’ allocations if, for example, the resultant allocations are deemed as reasonable and acceptable by associated stakeholders. For [2], these algebraic allocations were internationally accepted.

For most services, the COCR assumes a statistical allocation of latency based on a Poisson distribution. The allocation among system components is done using mean (average) delay values.

For data services that are characterised as air-ground (includes AOC services), the major segments in the end-to-end connection include: the ground end/host system automation segment, the ground network segment, the FRS segment, the airborne end system (the airborne equipment external to the FRS - refer to the FRS Boundary Point discussion). The percentage allocations for each of these segments are 25%, 25%, 40%, and 10%, respectively. Details of the allocation process are given in Appendix E.

For the SURV (all types), WAKE and TIS-B data services, the FRS allocation is assumed to be **33%** for high performance services (e.g., PIARAPP SURV) and **60%** for the remaining services. These allocations are based on [5] and assume a broadcast service FRS boundary point.

Note: Since the statistical distribution of the air-air delays is not well known, an algebraic allocation is used.

The allocation percentages for Phase 1 and Phase 2 are the same.

5.2.2.2.2 Integrity

Integrity requirements on the FRS were calculated based on the assumption that it must contribute no more than **50%** of the errors. This generous allocation is made to the FRS because of significantly higher data error rates associated with RF transmission.

5.2.2.2.3 Availability

Availability requirements on the FRS were calculated based on the assumption that it must contribute no more than **50%** of the errors. This generous allocation is made to the FRS because of the impact of interference on operational availability. If it were not for interference, the allocation to the FRS would be much lower since the expected inherent availability (equipment performance) is not significantly different from other communication equipment.

5.2.2.2.4 Continuity & Expiration Time

For most services, continuity and expiration time requirements on the FRS were calculated by arithmetically allocating **80%** of the expiration time to the FRS and **80%** of the continuity to the FRS. It is assumed that most unexpected interruptions to the transaction are due to RF conditions. In addition, the use of an arithmetic allocation is more appropriate when allocating delays with high confidence levels, since unpredictable delays may arise from systematic effects such as anomalies in coverage or handoffs, which are not readily susceptible to purely statistical treatment.

Note: The allocation of continuity and expiration time are the subject of continuing discussion and refined values are possible in future documents.

5.2.2.2.5 Update Interval

Note: The update interval for broadcast services is not allocatable to communication segments, e.g., the FRS.

5.2.2.3 FRS Performance Values

Table 5-7, Table 5-8, and Table 5-9 provide the performance requirements for the FRS.

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95}- 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UTT}	I_{UCT}	A_P	A_U
ACL	8.0	8.0	8.0	60.0	-	3.8	3.8	3.8	26.5	-	0.996[5]	5.0E-6	0.9995	0.9965[6]
ACM	8.0	8.0	8.0	60.0	-	3.8	3.8	3.8	26.5	-	0.996	5.0E-6	0.9995	0.9965
A-EXEC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AIRSEP	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AIRSEP SURV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AMC	8.0	8.0	8.0	-	-	3.8	3.8	3.8	-	-	0.996	5.0E-4	0.9995	0.9965
ARMAND	-	-	24.0	-	-	-	-	9.2	-	-	0.996	5.0E-6	0.9995	0.9965
C&P ACL	-	16.0	16.0	60.0	-	-	5.7	5.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
C&P SURV	-	4.8	4.8	4.8	-	-	1.2	1.2	1.2	-	0.9996	5.0E-8	0.9995	0.9995
COTRAC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D-ALERT	16.0	16.0	16.0	60.0	-	5.7	5.7	5.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
D-ATIS	12.0	12.0	12.0	72.0	-	4.7	4.7	4.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
DCL	24.0	-	-	-	-	9.2	-	-	-	-	0.996	5.0E-6	0.9995	0.9965
D-FLUP	24.0	-	-	-	-	9.2	-	-	-	-	0.996	5.0E-4	0.9995	0.9965
DLL	16.0	16.0	16.0	80.0	-	5.7	5.7	5.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
D-ORIS	-	12.0	12.0	72.0	-	-	4.7	4.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
D-OTIS	12.0	12.0	12.0	72.0	-	4.7	4.7	4.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
D-RVR	12.0	12.0	12.0	72.0	-	4.7	4.7	4.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
DSC	-	-	48.0	57.6	-	-	-	22.2	26.5	-	0.996	5.0E-6	0.9995	0.9965
D-SIG	24.0	24.0	-	-	-	9.2	9.2	-	-	-	0.996	5.0E-6	0.9995	0.9965
D-SIGMET	12.0	12.0	12.0	57.6	-	4.7	4.7	4.7	26.5	-	0.996	5.0E-6	0.9995	0.9965
D-TAXI	16.0	16.0	-	-	-	5.7	5.7	-	-	-	0.996	5.0E-6	0.9995	0.9965
DYNAV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FLIPCY	32.0	32.0	32.0	64.0	-	13.6	13.6	13.6	26.5	-	0.996	5.0E-6	0.9995	0.9965
FLIPINT	32.0	32.0	32.0	64.0	-	13.6	13.6	13.6	26.5	-	0.996	5.0E-6	0.9995	0.9965
ITP ACL	-	-	-	60.0	-	-	-	-	26.5	-	0.996	5.0E-6	0.9995	0.9965
ITP SURV	-	4.8	4.8	4.8	-	-	1.2	1.2	1.2	-	0.9996	5.0E-8	0.9995	0.9995
M&S ACL	-	16.0	16.0	-	-	-	5.7	5.7	-	-	0.996	5.0E-6	0.9995	0.9965
M&S SURV	-	4.8	4.8	4.8	-	-	1.2	1.2	1.2	-	0.9996	5.0E-8	0.9995	0.9995
PAIRAPP ACL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAIRAPP SURV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PPD	32.0	32.0	32.0	32.0	-	13.6	13.6	13.6	26.5	-	0.996	5.0E-6	0.9995	0.9965
SAP	-	12.0	12.0	-	-	-	4.7	4.7	-	-	0.996	5.0E-6	0.9995	0.9965
SURV (ATC)	3.2	8.0	16.0	16.0		0.4	1.2	1.2	1.2	-	0.99996	5.0E-8	0.9999975	0.99995
TIS-B	3.2	8.0	16.0	16.0	-	0.4	1.2	1.2	1.2	-	0.99996	5.0E-8	0.9999975	0.99995
URCO	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAKE	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5-7: Phase 1 ATS FRS Performance Requirements

[5] For the ORP domain, the FRS continuity requirement is 0.9995.

[6] For the ORP domain, the FRS availability of use requirement is 0.9995.

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95}- 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UIT}	I_{UCT}	A_P	A_U
ACL	5.0	5.0	5.0	16.0	5.0	1.4	1.4	1.4	5.9	1.4	0.9996	5.0E-8	0.999995	0.9995
ACM	5.0	5.0	5.0	16.0	5.0	1.4	1.4	1.4	5.9	1.4	0.9996	5.0E-8	0.999995	0.9995
A-EXEC	-	1.6	1.6	1.6	-	-	0.74	0.74	-	-	0.99999992	5.0E-10	0.9999999995	0.99999995
AIRSEP	-	-	-	-	7.8	-	-	-	-	2.4	0.9996	5.0E-8	0.999995	0.9995
AIRSEP SURV	-	-	-	-	8.0	-	-	-	-	1.2	0.9996	5.0E-8	0.999995	0.9995
AMC	8.0	8.0	8.0	-	24.0	3.8	3.8	3.8	-	9.2	0.996	5.0E-4	0.9995	0.9965
ARMAND	-	-	13.6	-	-	-	-	4.7	-	-	0.996	5.0E-4	0.9995	0.995
C&P ACL	-	7.8	7.8	16.0	-	-	2.4	2.4	5.9	-	0.9996	5.0E-8	0.999995	0.9995
C&P SURV	-	4.8	4.8	4.8	-	-	1.2	1.2	1.2	-	0.9996	5.0E-8	0.9995	0.9995
COTRAC	-	7.8	7.8	16.0	7.8	-	2.4	2.4	5.9	2.4	0.9996	5.0E-8	0.999995	0.9995
D-ALERT	7.8	7.8	7.8	16.0	7.8	2.4	2.4	2.4	5.9	2.4	0.9996	5.0E-6	0.999995	0.9995
D-ATIS	7.8	7.8	7.8	24.0	24.0	2.4	2.4	2.4	9.2	9.2	0.996	5.0E-8	0.9995	0.995
DCL	24.0	-	-	-	-	9.2	-	-	-	-	0.9996	5.0E-8	0.999995	0.9995
D-FLUP	7.8	7.8	13.6	24.0	24.0	2.4	2.4	4.7	9.2	9.2	0.996	5.0E-4	0.9995	0.995
DLL	7.8	7.8	13.6	24.0	24.0	1.4	2.4	4.7	9.2	9.2	0.9996	5.0E-8	0.999995	0.9995
D-ORIS	-	7.8	7.8	24.0	24.0	-	2.4	2.4	9.2	9.2	0.996	5.0E-8	0.9995	0.995
D-OTIS	7.8	7.8	7.8	24.0	24.0	2.4	2.4	2.4	9.2	9.2	0.996	5.0E-8	0.9995	0.995
D-RVR	5.0	5.0	7.8	24.0	24.0	1.4	1.4	2.4	9.2	9.2	0.996	5.0E-8	0.9995	0.995
DSC	-	-	24.0	16.0	24.0	-	-	9.2	22.2	9.2	0.9996	5.0E-8	0.999995	0.9995
D-SIG	13.6	13.6	-	-	-	4.7	4.7	-	-	-	0.996	5.0E-8	0.9995	0.995
D-SIGMET	7.8	7.8	7.8	24.0	24.0	2.4	2.4	2.4	9.2	9.2	0.996	5.0E-8	0.9995	0.995
D-TAXI	7.8	7.8	-	-	-	2.4	2.4	-	-	-	0.9996	5.0E-8	0.999995	0.9995
DYNAV	-	-	13.6	24.0	-	-	-	4.7	9.2	-	0.996	5.0E-4	0.9995	0.995
FLIPCY	7.8	7.8	7.8	16.0	7.8	2.4	2.4	2.4	5.9	2.4	0.9996	5.0E-8	0.999995	0.9995
FLIPINT	7.8	7.8	7.8	16.0	7.8	2.4	2.4	2.4	5.9	2.4	0.9996	5.0E-8	0.999995	0.9995
ITP ACL	-	7.8	7.8	16.0	-	-	2.4	2.4	5.9	-	0.9996	5.0E-8	0.999995	0.9995
ITP SURV	-	4.8	4.8	4.8	-	-	1.2	1.2	1.2	-	0.9996	5.0E-8	0.9995	0.9995
M&S ACL	-	7.8	7.8	16.0	-	-	2.4	2.4	5.9	-	0.9996	5.0E-8	0.999995	0.9995
M&S SURV	-	4.8	4.8	4.8	-	-	1.2	1.2	1.2	-	0.9996	5.0E-8	0.9995	0.9995
PAIRAPP ACL	-	7.8	-	-	-	-	2.4	2.4	-	-	0.9996	5.0E-8	0.999995	0.9995
PAIRAPP SURV	3.2	3.2	-	-	-	0.4	0.4	-	-	-	0.99996	5.0E-8	0.9995	0.9995
PPD	13.6	13.6	13.6	24.0	24.0	4.7	4.7	4.7	9.2	4.7	0.996	5.0E-4	0.9995	0.995
SAP	-	7.8	7.8	-	-	-	2.4	2.4	-	-	0.9996	5.0E-8	0.999995	0.9995
SURV (ATC)	3.2	8.0	8.0	8.0	8.0	0.4	1.2	1.2	1.2	1.2	0.99996	5.0E-8	0.9999975	0.99995
TIS-B	-	-	-	-	-	-	-	-	-	-	-	-	-	-
URCO	7.8	7.8	7.8	16.0	7.8	2.4	2.4	2.4	5.9	2.4	0.9996	5.0E-6	0.999995	0.9995
WAKE	3.2	8.0	8.0	-	-	0.4	1.2	1.2	-	-	0.9996	5.0E-8	0.9995	0.9995

Table 5-8: Phase 2 ATS FRS Performance Requirements

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95}- 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UIT}	I_{UCT}	A_P	A_U
AOCDLL	Not Available					13.6	13.6	13.6	26.5	26.5	Not Available	5.0E-8	0.9995	0.995
CABINLOG						26.5	-	-	-	-		5.0E-4	0.9995	0.995
ENGINE						26.5	26.5	26.5	51.7	51.7		5.0E-5	0.9995	0.995
FLTLOG						26.5	-	-	-	-		5.0E-4	0.9995	0.995
FLTPLAN						13.6	13.6	13.6	26.5	26.5		5.0E-8	0.9995	0.9995
FLTSTAT						13.6	13.6	13.6	26.5	26.5		5.0E-4	0.9995	0.995
FREETXT						26.5	26.5	26.5	51.7	51.7		5.0E-4	0.9995	0.995
FUEL						26.5	26.5	26.5	51.7	51.7		5.0E-4	0.9995	0.995
GATES						13.6	13.6	13.6	26.5	26.5		5.0E-4	0.9995	0.995
LOADSHT						13.6	13.6	-	-	-		5.0E-8	0.9995	0.995
MAINTPR						13.6	13.6	13.6	26.5	26.5		5.0E-5	0.9995	0.995
MAINTRT						26.5	26.5	26.5	51.7	51.7		5.0E-5	0.9995	0.995
NOTAM						26.5	26.5	26.5	51.7	51.7		5.0E-8	0.9995	0.995
OOOI						13.6	-	-	-	-		5.0E-4	0.9995	0.995
POSRPT						26.5	26.5	26.5	51.7	51.7		5.0E-5	0.9995	0.995
SWLOAD						26.5	26.5	26.5	51.7	51.7		5.0E-10	0.9995	0.995
TECHLOG						26.5	-	-	-	-		5.0E-5	0.9995	0.995
UPLIB						26.5	26.5	26.5	51.7	51.7		5.0E-8	0.9995	0.995
WXGRAPH						13.6	13.6	13.6	26.5	26.5		5.0E-8	0.9995	0.995
WXRT						13.6	13.6	13.6	26.5	26.5		5.0E-8	0.9995	0.995
WXTEXT						13.6	13.6	13.6	26.5	26.5		5.0E-8	0.9995	0.995

Table 5-9: FRS Allocated Data Performance Requirements (AOC)

6 COMMUNICATION LOADING ANALYSES

6.1 Introduction

This section provides an **estimate** of the FRS communication load associated with ATS and AOC services. The purpose of the loading estimate is to facilitate operational service evaluation and FRS technology assessment. Although this estimate is based on one set of reasonable assumptions, an equally reasonable but alternate set of assumptions may result in a different estimate.

The first major assumption divides the loading analysis into three major pieces:

- Voice Loading Analysis
- Addressed Data Loading Analysis
- Broadcast Data Loading Analysis

Section 6.2 documents the detailed assumptions used in each of the three FRS loading analyses. The section includes assumptions about broadcast versus addressed data service implementations, the aggregation and prioritization of information flows, operational volumes, user quantities, operational service utilization rates, message sizes, equipage, and other related information.

Each analysis estimates the information transfer rate needed for each operational volume. It should be clearly understood that the analyses contained in this section are intended to be technology independent. The capacity requirements are intended to provide a sense of overall information transfer rates and not the required RF bit transmission rates. Since coverage volumes associated with communication technologies can be varied, the COCR uses operational volumes. Two types of operational volumes are defined: a service volume and a transmission volume. Service volumes are used for addressed communication. Transmission volumes are used for broadcast communication. A transmission volume is based on operational need and not on technology capabilities. Once loading estimates are established for an operational volume, traffic rates and capacities for communication technology coverage volumes can be developed.

The Voice Loading Analysis is presented in Section 6.3. The analysis estimates the utilization of the party line voice channel for a service volume. The voice utilization rates are moderated based on anticipated data utilization rates. While use of data communications reduces voice channel occupancy, this analysis insures that the increase in air traffic per sector/position can still be accommodated by the existing party line channel. While the COCR does not require any new voice services, this section provides voice access rates and durations which can be used to assess alternate voice service technologies.

The Addressed Data Loading Analysis is presented in Section 6.4. This analysis provides the estimated communication load associated with addressed data communications in a service volume. Various combinations of information flows are analyzed. ATS and AOC traffic load is evaluated separately and together. Uplink and downlink transmissions are evaluated separately and together. A queueing model, service classes, and service priorities are assumed to estimate the required information transfer rate.

The Broadcast Data Loading Analysis is presented in Section 6.5**.** This analysis looks at broadcast communication loading associated primarily with surveillance services, e.g., SURV, TIS-B and WAKE. This analysis assumes a shared channel and uses a transmission volume.

Each analysis includes a description of the estimating methodology, the estimated communication load, and an analysis of the results.

6.2 Loading Analyses Assumptions

The communication loading analyses are based on a number of assumptions. The assumptions are grouped into two major sets:

- **Operational and Environmental Assumptions:** These include service usage information in an operational context. Information on equipage and number of users is provided. These assumptions are independent of communication technology.
- **Communication Implementation Assumptions:** These include implementation assumptions necessary to estimate communication loading. Assumptions are made about whether a service uses an addressed or broadcast implementation. Information on network management, classes of service, message quantities, and message sizes are provided.

The next two sections provide details on each set of assumptions.

6.2.1 Operational and Environmental Assumptions

The following operational and environmental assumptions are used by one or more of the communication loading analyses.

- **Operational Volume:** Operational volumes provide the context for identifying the number of users and for developing service usage information. Two types of services volumes are defined: service volumes and transmission volumes.
- **Service Instances:** The service instances represent the typical number of times a service is used within an operational volume.
- **Flight Duration per Service Volume:** The flight durations for each service volume are provided. The service instances and flight duration per service volume are used to develop average message arrival rates. Average message arrival rates are used within the Addressed Data Loading Analysis.
- **Equipage and Voice/Data Utilisation:** Service utilisation rates are dependent on whether users are equipped to use a particular service.
- **Number of Users:** The Peak Instantaneous Aircraft Count (PIAC) represents worst case number of users for a given operational volume. The number of Daily Operations per Domain is also provided.

6.2.1.1 Operational Volumes

An operational volume (OV) is a defined operational area in which services are provided. Operational volumes are defined within each of the airspace domains. The COCR defines two types of operational volumes:

- **Service Volume (SV):** A volume of airspace that aligns with ATC sector/position control boundaries. For all domains except the APT, it is a volume of airspace in which all aircraft are controlled by a single Controller position. For the APT, the service volume encompasses all APT airspace sectors/positions in the domain. Although the volume boundaries align with controlled airspace, the COCR evaluates all types of communication in this area including flight information services, controller-pilot communication, and aircraft-provided state/intent data. Service volumes provide the operational context for addressed services.
- **Transmission Volume (TV):** A volume of airspace that is based on range or distance. Transmission volumes are most applicable for broadcast services, because broadcasted services reach all users within the range of the broadcast. In the COCR, ranges are based on operational need and not the capabilities of a particular technology.

While these volumes have an operational context, the volume may or may not be well matched to a particular communication technology. The designated operational coverage (DOC) for a particular technology will be dependent on the characteristics of that technology, e.g., power, frequency, bit rate. The aim is to identify a communication ‘density’ requirement for each coverage volume independent of communications technology. By combining the operational volumes into typical DOC for technologies the communication requirement can be obtained per DOC. Knowledge of the deployment of operational volumes is important and sufficient details need to be provided to enable technology choices to be matched to the communication requirement.

6.2.1.1.1 Service Volumes

A typical flight may cross several airspace domains including APT, TMA, ENR, ORP and/or AOA.

In the case of the Airport service volume, the entire domain was used as the volume rather than a single position; thus, this volume includes the clearance/ramp position, the ground position, and the tower/runway position. The airport service volume equates to a cylinder, 10 miles in diameter, from ground to an altitude of 5,000 feet.

The sizes of service volumes for Phase 1 are equivalent to control positions/sectors in existence today. Use of the new operational services in Phase 1 will allow higher numbers of aircraft to be serviced in the same volume. For Phase 2, it is assumed the TMA, ENR and ORP service volumes are about three times the size used in Phase 1.

Note: In the En Route domain, an ATSU will have more than 1 sector, but a given aircraft will only fly through 1 sector in each ATSU due to the size expansion.

As these types of airspace can vary widely in their requirements depending on the level of air traffic, for each service volume a typical high-density and low-density example was defined. The autonomous service volume is the only volume that does not include high and low density examples.

6.2.1.1.2 Transmission Volumes

Transmission volumes apply to broadcasted services. The COCR defines two types of transmission volumes:

- **Domain-Based Volume:** These volumes assume each domain is separate and independent from the others. In other words, while the TMA and ENR domains may overlap from a transmission range standpoint, the analysis assumes the transmissions from an aircraft in the TMA but near the boundary of ENR do not interfere with transmissions in the ENR domain.
- **Fixed Range Volume:** These volumes do not consider domain boundaries and are based sole on transmission range. The COCR only considers fixed range volumes that span the APT, TMA, and ENR domains.

Table 6-1 describes the transmission ranges for each volume.

Transmission Volume	Range (NM)				
	APT	TMA	ENR	ORP	AOA
Air-Air SURV	5	60	100	100	100
Air-Ground SURV	5	100	200	200	-
100 NM Fixed Range	100			-	-
150 NM Fixed Range	150			-	-

Table 6-1: Transmission Volume Ranges

6.2.1.2 Service Instances

Table 6-2 to Table 6-4 provide the expected number of usage instances for ATS and AOC data services in Phase 1 and Phase 2.

For ATS instances, usage is provided on a per aircraft per service volume basis except for the A-EXEC and AMC services (see ** in tables) which are provided on a per ATSU basis (not per aircraft). To translate these services into a per aircraft per service volume basis, one must know the number of aircraft, i.e., operations, that are served by the ATSU over the applicable timeframe (e.g., one year or one week). See Section 6.2.1.5.3 for the number of operations per ATSU.

For Phase 2, Table 6-3 also provides two columns to present service instance applicability for each of the two types of data communications equipped aircraft, i.e., basic data communications (Type I) and COTRAC equipped (Type II), as described in Section 6.2.1.4. For example, the ARMAND service continues to be used by basic data communications equipped aircraft in Phase 2. However, this service is typically not used by COTRAC equipped aircraft in Phase 2, because COTRAC functionality supersedes the need to use this service.

Note: In Phase 2 sector sizes have become larger than Phase 1. In the ENR domain, an ATSU will have more than 1 sector, but a given aircraft will only fly through 1 sector in each ATSU due to the size expansion.

For the AOC instances, it is assumed that the number of instances is the same in Phase 1 and Phase 2; however, the number of messages per instance and/or the message sizes may be different in each phase.

Service	APT	TMA	ENR	ORP
ACL	1 (in ground position), both departure and arrival	2 per sector, both departure and arrival	5 per domain	2 per domain
ACM	3 per domain (1 in each position), both departure and arrival	1 per sector, both departure and arrival	1 per sector	1 per sector
A-EXEC	-	-	-	-
AIRSEP	-	-	-	-
AIRSEP SURV	-	-	-	-
AMC** (per ATSU)	1 per ATSU, per week	1 per ATSU, per week	1 per ATSU, per week	0
ARMAND	0	0	1 per domain, arrival only	0
C&P	0	0	1 per domain	1 per domain
C&P SURV	0	0	Once every 3 s	Once every 3 s
COTRAC	-	-	-	-
D-ALERT	1 per aircraft per year	1 per aircraft per year	1 per aircraft per year	1 per aircraft per year
D-ATIS (Arrival)	0	1 per domain arrival for 70% of aircraft	1 per domain arrival for 70% of aircraft	0
D-ATIS (Departure)	1 (in ramp position), departure only for 70% of aircraft	0	0	0
DCL	1 (in ramp position), departure only	0	0	0
D-FLUP	1 (in ramp position), departure only	0	0	0
DLL	1 (in ramp position), departure only	0	1 per domain 30% of the time	1 per domain, 30% of the time
D-ORIS	0	0	1 per domain	1 per domain
D-OTIS	1 (in ramp position), departure only for 30% of aircraft	1 per domain, arrival only for 30% of aircraft	1 per domain for 30% of aircraft	0
D-RVR	1 (in ramp position), 30% of the time, departure only	1 per domain, 30% of the time during arrival	1 per domain, 30% of the time during arrival	0
DSC	0	0	1 per domain	1 per domain
D-SIG	1 (in ramp position), departure only	1 per domain, arrival only	0	0
D-SIGMET	1 (in ramp position), 30% of the time, departure only	1 per domain, 30% of the time during arrival	1 per domain, 30% of the time	1 per domain, 30% of the time
D-TAXI	1 (in ground position), both departure and arrival	1 per domain, arrival only	0	0
DYNAV	-	-	-	-
FLIPCY	1 (in ramp position), departure only	1 per domain, departure only	1 per domain	1 per domain
FLIPINT	1 (in ramp position), departure only	1 per domain	1 per ATSU	6 per sector
ITP	0	0	0	1 per domain

Service	APT	TMA	ENR	ORP
ITP SURV	0	0	0	Once every 3 s
M&S	0	1 per domain arrival only	1 per domain arrival only	0
M&S SURV	0	Once every 3 s	Once every 3 s	0
PAIRAPP ACL	-	-	-	-
PAIRAPP SURV	-	-	-	-
PPD	1 (in ramp position), departure only	1 per domain, both departure and arrival	1 per domain	1 per domain
SAP (Contract Establishment)	0	1 per ATSU	1 per ATSU	0
SAP (Periodic Report)	0	Once every 10 s	Once every 10 s 30% of the time	0
SURV (ATC)	Once every 2 s	Once every 5 s	Once every 10 s	Once every 10 s
TIS-B	Once every 2 s	Once every 5 s	Once every 10 s	-
URCO	-	-	-	-
WAKE	-	-	-	-

Table 6-2: Phase 1 ATS Service Instances per Aircraft

Service	Type[7] I	Type[7] II	APT	TMA	ENR	ORP	AOA (Type II only)
ACL	X	X	Type I&II: 1 (in ground position), both departure and arrival	Type I&II: 2 per sector, both departure and arrival	Type I: 5 per domain Type II: 1 per domain	Type I: 2 per domain Type II: 1 per domain	0
ACM	X	X	3 per domain (1 in each position), both departure and arrival	1 per sector, both departure and arrival	1 per sector	1 per sector	1 per domain (in buffer zone)
A-EXEC** (per ATSU)	-	X	0	1 per year per ATSU	1 per year per ATSU	0	0
AIRSEP	-	X	0	0	0	0	2 per domain
AIRSEP SURV	-	X	0	0	0	0	Once every 5 s
AMC** (per ATSU)	X	X	1 per week per ATSU	1 per week per ATSU	1 per week per ATSU	0	0
ARMAND	X	-	0	0	1 per domain, arrival only	0	0
C&P ACL	X	-	0	0	1 per domain	1 per domain	0
C&P SURV	X	-	0	0	Once every 3 s	Once every 3 s	0
COTRAC[8]	-	X	1 (in ramp position) departure only	1 per domain, departure only	1 per sector	1 per sector	1 per domain in the buffer zone
D-ALERT	X	X	1 per aircraft per year	1 per aircraft per year	1 per aircraft per year	1 per aircraft per year	0
D-ATIS (Arrival)	X	X	0	1 per domain on arrival for 30% of aircraft	1 per domain on arrival for 30% of aircraft	0	0
D-ATIS (Departure)	X	X	1 (in ramp position), departure only for 30% of aircraft	0	0	0	0
DCL	X	-	1 (in ramp position), departure only	0	0	0	0

[7] Type I aircraft have basic data link equipage. Type II aircraft have COTRAC equipage. An 'X' in the column indicates the instances are applicable to that type of aircraft. A '-' in the column indicates the instances are not applicable for that type of aircraft.
[8] For Type II aircraft, 75% of the COTRAC exchanges are WILCO'd and 25% of them require a negotiation. When COTRAC is not available, aircraft will use Phase 1 services.

Service	Type[7] I	Type[7] II	APT	TMA	ENR	ORP	AOA (Type II only)
D-FLUP	X	X	1 (in ramp position), departure only	0	0	0	0
DLL	X	X	1 (in ramp position), departure only	0	1 per domain, 30% of the time	1 per domain, 30% of the time	1 per domain (in buffer zone)
D-ORIS	X	X	0	0	1 per domain	1 per domain	0
D-OTIS	X	X	1 (in ramp position), departure only for 70% of aircraft	1 per domain, arrival only for 70% of aircraft	1 per domain for arrival for 70% of aircraft	0	0
D-RVR	X	X	1 (in ramp position), 30% of the time, departure only	1 per domain, 30% of the time, arrival only	1 per domain, 30% of the time, arrival only	0	0
DSC	X	-	0	0	1 per domain	1 per domain	0
D-SIG	X	X	1 (in ramp position), departure only	1 per domain, arrival only	0	0	0
D-SIGMET	X	X	1 (in ramp position), 30% of the time, departure only	1 per domain, 30% of the time, arrival only	1 per domain 30% of the time	1 per domain 30% of the time	0
D-TAXI	X	X	1 (in ground position), departure and arrival	1 per domain, arrival only	0	0	0
DYNAV	-	X	0	0	1 per domain for 30% of aircraft	1 per domain for 30% of aircraft	0
FLIPCY	X	-	1 (in ramp position), departure only	1 per domain, departure only	1 per domain	1 per domain	0
FLIPINT	X	X	1 (in ramp position), departure only	1 per domain	1 per ATSU	1 per ATSU	1 per domain (in buffer zone)
ITP ACL	X	-	0	1 per domain, arrival only	1 per domain	1 per domain	0
ITP SURV	X	-	0	Once every 3 s	Once every 3 s	Once every 3 s	0
M&S ACL	X	-	0	1 per domain, arrival only	1 per domain	0	0
M&S SURV	X	-	0	Once every 3 s	Once every 3 s	0	0
PAIRAPP	-	X	0	1 per domain arrival only, 20% of the time	0	0	0
PAIRAPP SURV	-	X	Once every 2 s	Once every 2 s	0	0	0
PPD	X	X	1 (in ramp position), departure only	1 per domain, departure and arrival	1 per domain	1 per domain	0
SAP (Contract Establishment)	X	-	0	1 per ATSU	1 per ATSU	0	0
SAP (Periodic Report)	X	-	0	Once every 10 s	Once every 10 s 30% of the time	0	0
SURV	X	X	Once every 2 s	Once every 5 s	Once every 5 s	Once every 5 s	Once every 5 s
TIS-B	-	-	-	-	-	-	-
URCO	-	X	1 per aircraft per year	1 per aircraft per year	1 per aircraft per year	1 per aircraft per year	0
WAKE	X	X	Once every 2 s	Once every 5 s	Once every 5 s	-	-

Table 6-3: Phase 2 ATS Service Instances per Aircraft

Service	PHASE 1/2				PHASE 2
	APT	TMA	ENR	ORP	AOA
AOCDLL	1 per ramp dep	0	0	1 per domain	0
CABINLOG	1 per ramp arr	0	0	0	0
ENGINE	0	1 per domain	1 per domain (when cruise altitude is reached)	0	0
FLTLOG	1 per ramp arr	0	0	0	0
FLTPLAN	1 per ramp dep	0	1 per domain	1 per domain	1 per domain
FLTSTAT	0	0	1 per domain	1 per domain	2 per domain
FREETEXT	0	0	2 per domain	2 per domain	1 per domain
FUEL	0	1 per domain	2 per domain	2 per domain	2 per domain
GATES	0	0	1 at top of descent	0	0
LOADSHT	2 per ramp dep	1per domain, arrival only	0	0	0
MAINTPR	0	0	1 per domain for 5% of flights	1 per domain for 5% of flights	1 per domain for 5% of flights
MAINTRT	0	0	2 per domain	2 per domain	2 per domain
NOTAM	1 per ramp dep	0	2 per domain	2 per domain	0
OOOI	1 ramp dep 1 rwy takeoff 1 rwy landing 1 ramp arr	0	0	0	0
POSRPT	0	Every 15 min	Every 15 min	Every 15 min	Every 15 min
SWLOAD	1 per ramp dep	0	0	0	0
TECHLOG	1 per ramp dep	0	0	0	0
UPLIB	1 per ramp dep	0	0	0	0
WXGRAPH	1 per ramp dep	0	Every 20 min	Every 40 min	Every 20 min
WXRT	Takeoff: 1 rpt every 6s	Climb/descend: 1 rpt every 60s	Climb/descend: 1 rpt every 60s[9] Cruise: 1 rpt every 3 min	Cruise: 1 rpt every 3 min	Cruise: 1 rpt every 3 min
WXTEXT	1 per ramp dep	0	2 per domain	2 per domain	1 per domain

Table 6-4: AOC Service Instances per Aircraft[10]

[9] In TMA domain, there is no cruise portion (aircraft are either climbing or descending). In the ER domain Phase 1, assume ½ the time aircraft are in climb/descend and the remaining ½ aircraft are in cruise mode. In Phase 2 leave the time for climb/descend the same and increase the cruise time to fit the sector duration time.
[10] Abbreviations: dep = departure, arr = arrival, rpt = report, rwy = runway

6.2.1.3 Flight Duration per Service Volume

The flight duration per service volume were estimated in tandem with evaluation of a typical flight profile. The number of sectors and ATSUs traversed in each domain were also estimated. Table 6-5 provides a summary of this information.

Type	Phase Density	APT			TMA	ENR	ORP	AOA
		Ramp	Ground	Tower				
Domain Flight Time	P1-HD	3690 s (dep) [61.5 min] 1290 s (arr) [21.5 min]			486 s (dep) 848 s (arr)	5400 s [1.5 hr]	15300 s [4.25 hr]	N/A
	P1-LD	2310 s (dep) [38.5 min] 630 s (arr) [10.5 min]			378 s (dep) 660 (arr)	5400 s [1.5 hr]		
	P2-HD	2790 s (dep) [46.5 min] 1110 s (arr) [18.5 min]			388 s (dep) 678 s (arr)	4920 s [1.35 hr]	15300 s [4.25 hr]	5400 s [1.5 hr]
	P2-LD	1410 s (dep) [23.5 min] 570 s (arr) [9.5 min]			302 s (dep) 528 (arr)	4920 s [1.35 hr]		
#Sectors/ Positions Traversed per Flight	P1-HD	3			2	8	6	N/A
	P1-LD	2 (ramp & ground combined)			1	6		
	P2-HD	3			2	5	4	1
	P2-LD	2 (ramp & ground combined)			1	4		
#ATSUs Traversed per Flight	ALL	1			1	4	2	N/A
Sector/ Position Flight Time	P1-HD	2700 s (dep) 540 s (arr)	720 s (dep) 480 s (arr)	270 s	243 s (dep) 424 s (arr)	675 s [11.25 min]	2550 s [42.5 min]	N/A
	P1-LD	1800 s (dep) 240 s (arr)	360 s (dep) 240 s (arr)	150 s	378 s (dep) 660 (arr)	900 s [15 min]		
	P2-HD	1800 s (dep) 360 s (arr)	720 s (dep) 480 s (arr)	270 s	194 s (dep) 339 s (arr)	984 s [16.4 min]	3825 s [63.75 min]	5400 s [90 min]
	P2-LD	900 s (dep) 180 s (arr)	360 s (dep) 240 s (arr)	150 s	302 s (dep) 528 (arr)	1230 s [20.5 min]		

Table 6-5: Phase 1 and 2 Flight Durations and Sectors/ATSUs Traversed

The APT service volume was split into flight duration for each position (clearance/ramp, ground, and tower/runway), as was the case for PIACs and service instances. Different durations were assigned, based on whether the aircraft was in departure mode or arrival mode in the APT for a particular flight. While the flight durations for the ground and tower positions are the same in Phase 1 and Phase 2, it is expected that the clearance/ramp flight duration will be shorter in Phase 2 due to more efficient turn-around.

For the TMA and ENR domains, it is assumed that domain flight times in Phase 2 are reduced due to better planning and the use of 4D trajectories which provide more direct routing. For the ENR domain, the Phase 2 sector sizes have become larger than Phase 1, thereby reducing the number of sectors traversed. An ENR ATSU will have a number of sectors, but a given aircraft will only fly through 1 sector (on average) due to the sector size expansion.

6.2.1.4 Equipage and Voice/Data Utilisation

Table 6-6 provides assumptions for data communications equipage and ATS voice vs. data service utilisation. For loading purposes, it is assumed that 100% of the aircraft in all domains are equipped to support AOC data communication and that AOC voice communication is so limited that it does not contribute to system loading.

	Phase	APT	TMA	ENR	ORP	AOA
% Data communications Equipage	1	75%	75%	75%	80%	-
	2	85%	85%	100%	100%	100%
% Services conducted using Voice	1	60%	60%	40%	5%	-
	2	15%	15%	5%	1%	1%

Table 6-6: ATS Service Equipage and Voice/Data Utilisation Rate

The data communications equipage percentages reflect the assumed number of aircraft with some form of data communications equipage. It is anticipated that there may be two levels of data communications functionality. While the link technology itself is assumed to be the same for all equipped aircraft, some of the aircraft will continue to support only Phase 1 types of services in Phase 2 APT and TMA domains.

It is also anticipated that 20% of the data communications equipped aircraft in these domains have basic equipage, i.e., do not support COTRAC, DYNAV, URCO, PAIRAPP, AIRSEP, and A-EXEC and are referred to as Type I aircraft in the loading analysis. Of the remaining 80%, 75% will provide simple WILCO responses to the COTRAC message while 25% negotiate the COTRAC utilising the message sequence structure for COTRAC described in Section 2. These latter aircraft are referred to as Type II aircraft.

The difference in the ENR/ORP/AOA versus TMA/APT data communications equipage figures in Table 6-6 is from the belief that in Phase 2, ENR/ORP/AOA airspace is assumed to mandate data communications equipage. In TMA/APT, some unequipped aircraft will continue to operate mixed in with data communications equipped aircraft due to business case considerations. These unequipped aircraft remain in the TMA for the cruise phase of flight. Some high density TMAs will be classified as mandatory equipage during peak periods. The net TMA equipage is assumed to be 85%.

While Table 6-6 provides the anticipated equipage and data utilisation percentages (on average), the addressed and broadcast data loading analyses assume 100% for all service volumes in order to generate worst case loading result. It also should be noted that the ATS and AOC data instances provided in Section 6.2.1.2 already take the voice/data utilisation into account. The voice loading analysis uses both the data communications equipage and ATS voice vs. data service utilisation rates to estimate voice loading.

6.2.1.5 Number of Users

This section includes information on:

- Service Volume PIACs
- Transmission Volume PIACs
- Daily Operations Per Domain

Most service instances are provided on a per aircraft basis. The service instances per aircraft are multiplied by the service volume PIACs to get the total instances per service volume. Instances for two services are provided on an ATSU basis, i.e., A-EXEC and AMC. The daily operations per ATSU are provided in order to derive the associated message arrival rates.

6.2.1.5.1 Service Volume PIACs

The service volume PIACs are based on projections produced by two separate computer-based air traffic models as well as some estimates from subject matter experts to account for new airspace types (e.g., the AOA) and projected growth in sectors not accounted for in the referenced computer models. This section first introduces the computer models and the model predictions. It subsequently provides the final estimated/extrapolated service volume PIACs.

Two separate computer models were used to estimate PIACs for airspace volumes in Phase 1 and Phase 2. These were:

- EUROCONTROL's System for Traffic Assignment and Analysis at a Macroscopic Level (SAAM) tool which can simulate air traffic and provide data about the traffic through specified airspace volumes. See Appendix A for a description of SAAM.
- The MITRE Corporation's Center for Advanced Aviation System Development Mid Level Model uses a traffic demand forecasting known as the Terminal Area Forecast (TAF), which is a compilation of scheduled airline flights growth. TAF baseline data is benchmarked for 2004 by the FAA. TAF is further refined through the observations of the Enhanced Traffic Management System to determine unscheduled traffic. The model provides PIAC counts for 2004, 2013 and 2020. The PIAC counts for 2030 are extrapolated. See Appendix B for further details.

These two models complemented each other. The SAAM model is constrained by the growth in airport traffic and can supply information on all 'flow-control sectors' throughout the European Civil Aviation Conference (ECAC).

The Mid-Level Model (MLM) supplied information on aircraft numbers operating in En Route sectors over the United States (U.S.) in the 2020 timeframe based on current practices. The National Airspace System (NAS) MLM modelling concept was to move the additional traffic to satellite airports. This is consistent with the U.S. Next Generation Air Transportation System (NGATS) vision [6]. Complete modelling to simulate the full 3 times traffic growth scenario and the concepts for 2025 were not completed. U.S. concepts also included the addition of thousands of Micro jets and UASs.

The operational concept in Phase 2 assumes that sector sizes are three times larger in the TMA, ENR, and ORP domains. This growth in service volume sizes could not be directly modelled in the SAAM and MLM models. However, three adjacent sectors were combined into one larger sector to estimate the Phase 2 PIAC. The SAAM model uses 'flow sectors'; those used in the calculations approximated to ATC control sectors. The MLM NAS sectors are based upon actual control sectors. These aspects are discussed further in Section 7.

Peak instantaneous aircraft counts (PIACs) were predicted for the years 2020 and 2030 using the SAAM and MLM models. The PIACs for the various service volumes are given in Table 6-7. Neither the SAAM nor the MLM could model the airport surface domain therefore this domain was treated separately using a number of sources. The airport domain in a busy U.S. airport was used as the basis for requirements.

The AOA service volume PIAC was estimated at 20% of the traffic density projected for the Phase 2 high density ENR service volume. Note: The AOA service volume is significantly larger than the ENR service volume.

Scenario	Date	APT		TMA		ENR		ORP		AOA
		HD	LD	HD	LD	HD	LD	HD	LD	
ECAC	2020	-	-	16	14	24	24	-	-	-
NAS	2020	200	12	-	-	41	-	10	5	-
ECAC	2030	-	-	44	39	45	59[11]	-	-	-
NAS	2030	290	19	-	-	95	-	34	18	70

Table 6-7: Service Volume PIACs

For the APT service volume, additional details about the distribution of aircraft amongst the three control positions must be known since many of the instances of service usage are specific to a particular control position. Table 6-8 summarises the number of aircraft assumed to be in the clearance/ramp, ground, and tower positions in Phase 1 and Phase 2.

[11] The PIAC for the ECAC ENR LD volume is larger than the HD volume, but the size of the service volume is much larger resulting in an overall lower density – see Section 7.

APT Position	Phase 1		Phase 2	
	HD	LD	HD	LD
Clearance/Ramp	134	4	194	7
Ground	48	3	70	4
Tower	18	5	26	8
Total	200	12	290	19

Table 6-8: Airport Controller Position PIACs

While not currently included within the loading analyses, it is important to note that in the airport environment, communication is necessary among a wide range of users in addition to the aircraft, e.g., surface vehicles. The FRS should have capacity to support this requirement although not necessarily in the same radio spectrum as aircraft. Table 6-9 provides the expected number of airport surface vehicles for Phase 1 and 2. Table 6-10 provides the number of the types of vehicles for a high-density airport.

APT	Phase 1		Phase 2	
	HD	LD	HD	LD
Surface Vehicles	32	4	32	8

Table 6-9: Airport Surface Vehicle Peak Counts

Vehicle Type	Number of Vehicles
Busses	12
De-icing Trucks	2
Snow Trucks	8
Airport Operations	6
Security and Fire Trucks	4
Total	32

Table 6-10: Types of Surface Vehicles

6.2.1.5.2 Transmission Volume PIACs

Table 6-11 provides PIACs for Phase 1 and Phase 2 transmission volumes. PIACs are based on the required transmission range associated with each service.

Services	Phase 1 PIAC					Phase 2 PIAC				
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA
C&P SURV	-	125	250	3	-	-	160	320	14	-
ITP SURV	-	125	250	3	-	-	160	320	14	-
M&S SURV	-	125	250	3	-	-	160	320	14	-
PAIRAPP SURV	-	-	-	-	-	6	18	-	-	-
AIRSEP	-	-	-	-	-	-	-	-	-	12
AIRSEP SURV	-	-	-	-	-	-	-	-	-	36
SURV	232	300	850	3	-	322	400	1100	14	-
TIS-B (note 1)	232	300	850	3	-	-	-	-	-	-
WAKE	-	-	-	-	-	26	400	1100	14	-
100 NM Fixed Range	475	300	250	-	-	600	400	320	-	-
150 NM Fixed Range	700	600	500	-	-	900	800	640	-	-

Table 6-11: Transmission Volume PIACs

The APT and ORP PIACs for SURV and TIS-B are based on the aircraft and surface vehicle PIACs described in Section 6.2.1.5.1.

The PAIRAPP PIAC is assumed to involve 20% of the arriving aircraft. The PAIRAPP service is used by aircraft on (or being sequenced to) final approach. The intended use of PAIRAPP is not completely compatible with the transmission volume boundaries selected for the air-air data loading analysis. The operation begins in the TMA domain and continues through the APT domain. The figures above are based on 20% of the arrival PIACs described in Section 6.2.1.5.1 with the total rounded up to the next even number.

For the AIRSEP PIAC, it is assumed that 50% of the aircraft in the AOA domain are clustered in an area with a 200 NM diameter. This yields a total PIAC of 36 within a 100 NM radius. It is assumed that one-third of the aircraft are conducting AIRSEP communication at any one point in time.

For the remaining volumes, the Phase 1 PIACs are estimated and the Phase 2 PIACs are based on an annual growth rate of 2.5% over a 10-year period.

6.2.1.5.3 Daily Operations Per ATSU

Table 6-12 and Table 6-13 provide the daily operations (number of aircraft serviced in a 24-hour period) per ATSU in Phase 1 and Phase 2, respectively. The Phase 2 daily operations are derived from the Phase 1 values by assuming a 2.5% annual growth rate over a ten-year period.

Density	Airport	TMA	En Route (40 sector domain)
High	1800	3000	12000
Low	50	300	400

Table 6-12: Phase 1 Daily Operations per ATSU

Density	Airport	TMA	En Route (40 sector domain)
High	2304	3840	15360
Low	64	384	512

Table 6-13: Phase 2 Daily Operations per ATSU

6.2.2 Communication Implementation Assumptions

The following communication implementation assumptions are used by one or more of the loading analyses.

- **Addressed and Broadcast Services:** Some operational services may be implemented via addressed and/or broadcasted communication services. The service implementation assumptions are described.
- **Network Management Services:** While transparent to end user operations, the FRS is assumed to be part of a network for addressed communications. The network requires connection and routing communication. This traffic is anticipated to flow over the FRS; therefore, assumptions about this traffic are described.
- **Service Message Quantities and Sizes:** Each instance of a data service may involve one or more messages that are exchanged between parties. For voice communication, the instance may involve series of voice transmissions, e.g., a Controller issues an instruction and the Flight Crew provides a confirmation reply. Data communications involve an analogous series of messages. Each message is assumed to include application data, network overhead, error check bits, and/or security data. Message quantities and sizes are described.
- **Communication Classes of Service:** Performance characteristics such as service priority and latency requirements drive system capacity requirements. Faster transaction times typically result in higher communication loading rates. The addressed loading analysis assumes that operational services are grouped into categories that are assigned a communication class of service (COS) and that each COS is assigned a priority relative to the others. The COS categories are defined and each operational service is mapped into an associated COS.

6.2.2.1 Addressed and Broadcasted Services

Many of the operational services described in Section 2 can be implemented via addressed and/or broadcast communication services. It has been assumed that the TIS-B, WAKE and SURV (all types) services are implemented via broadcast. It has been assumed that the addressed portion of the AIRSEP service has been implemented via a broadcast communication services (see Section 6.5 for details). All remaining services are assumed to be implemented using addressed implementations.

Note: The SAP service as well as all of the FIS services could be implemented via broadcast communication services. The broadcast loads for these services and the potential reductions in addressed communication load are not evaluated in the COCR

6.2.2.2 Network Management Services (NET)

Network management services are used to establish and maintain connections between each pair of aircraft and ground systems. The loading analysis assumes that there are two network management services — network connection and network keep-alive. This section describes the services and provides the instances of use per aircraft.

6.2.2.2.1 Network Connection (NETCONN)

A network connection is established between each pair of aircraft and ground systems before ATS or AOC data services can be provided between aircraft and ground entities. It is normally maintained between the aircraft system and a ground system for the entire length of the flight.

A connection establishment may be initiated by the aircraft or ground system. When the aircraft flies into the service area of the next ground system, it may have to establish a new connection with a next ground system and release a connection with the previous ground system.

The network connection service is a point-to-point service. It is normally used in all phases of the flight in all domains.

6.2.2.2.2 Network Keep-Alive (NETKEEP)

Once a connection is established, network keep-alive messages are exchanged between the aircraft and ground systems when there is no traffic for a period of time to maintain the status of the connection.

The network keep-alive service is a point-to-point service. It is normally used in all phases of flight in all domains.

6.2.2.2.3 NET Service Instances

Table 6-14 provides the assumed service utilization for the addressed data loading analysis.

Note: For purposes of estimating load, an Aeronautical Telecommunications Network (ATN) protocol stack is used. The COCR does not specify or require a particular network stack.

Service	**PHASE 1/2**				**PHASE 2**
	APT	**TMA**	**ENR**	**ORP**	**AOA**
NETCONN	1 (in ramp), departure only	0	1 per domain	1 per domain	1 per domain (in buffer zone)
NETKEEP	1 per 30 mins	1 per 30 mins	1 per 30 mins	1 per 30 mins	1 per domain (in buffer zone)

Table 6-14: NET Service Instances

6.2.2.3 Message Quantities and Sizes

Table 6-15 to Table 6-17 provide the average number of message quantities and sizes per service instance for ATS, AOC and NET services, respectively. For addressed services, message sizes are provided for the uplink and downlink directions. For broadcasted services, the message size is the transmitted message size.

For addressed messages, the message quantities and sizes are based on a number of referenced sources for some services and engineering estimates for the newer services, see [37], [38] and [40]. The messages include overheads associated with the network, integrity and security.

Note: For purposes of estimating load, the addressed message sizes assume an ATN protocol stack is used. The COCR does not specify or require a particular network stack.

The DLL and AOCDLL messages include 72 octets for network overhead and 4 octets for integrity. The security overhead for both types of messages include key exchanges and the overhead size varies based on the assumed number of applications supported. It is assumed that the DLL service supports 3 applications and the AOCDLL service supports 2 applications.

The AIRSEP message size is assumed to be a derivative of that used for the COTRAC service, since it is the air-air version of the same function. However, the quantity of information exchanged is smaller due to the smaller time horizons. The COTRAC is a complete trajectory while the AIRSEP only addresses the part of the trajectory needed to resolve the air-air conflict. Only a transmit message size is provided for AIRSEP because the loading analyses assume this addressed operational service is transmitted over a broadcasted communication service. See Section 6.5 for details.

The remaining addressed messages include includes 72 octets for network overhead, 4 octets for integrity overhead, and 1 octet for security overhead. Note: It is assumed that the security authentication value can be XORed with the integrity checksum to save bandwidth. Encryption adds overhead to the logon message, but not to the other application messages.

For broadcast messages, the SURV message size is assumed to be 34 bytes, i.e., the message size associated with UAT technology transmissions per RTCA DO-282A. This is the worst case message size associated with current air-air broadcast technologies. The WAKE message size is assumed to be the same as SURV.

Note: For some of the services, the average message quantities and sizes have been refined for Version 2.0 of the COCR and application level logical acknowledgements (LACKs) have been removed.

Services	**Uplink Qty x Size (bytes)**	**Downlink Qty x Size (bytes)**
ACL	2 x 93	2 x 93
ACM	1 x 126	1 x 88
A-EXEC	1 x 600	1 x 100
AIRSEP	6 x 497	

Services	Uplink Qty x Size (bytes)	Downlink Qty x Size (bytes)
AMC	1 x 89	0 x 0
ARMAND	1 x 260	1 x 88
C & P ACL	2 x 93	2 x 93
ITP SURV	1 x 34	
COTRAC (Interactive)	3 x 1969	4 x 1380
COTRAC (Wilco)	2 x 1613	2 x 1380
D-ALERT	1 x 88	1 x 1000
D-ATIS (Arrival)	5 x 100	3 x 93
D-ATIS (Departure)	3 x 101	2 x 96
DCL	1 x 117	2 x 88
D-FLUP	5 x 190	3 x 129
DLL	1 x 491	1 x 222
D-ORIS	9 x 478	3 x 93
D-OTIS	11 x 193	3 x 107
D-RVR	4 x 116	3 x 121
DSC	3 x 96	4 x 87
D-SIG	4 x 1340	3 x 129
D-SIGMET	4 x 130	3 x 129
D-TAXI	2 x 132	1 x 98
DYNAV	1 x 515	1 x82
FLIPCY	1 x 105	1 x 173
FLIPINT	1 x 143	1 x 2763
ITP ACL	2 x 93	2 x 93
ITP SURV	1 x 34	
M&S ACL	2 x 93	2 x 93
M&S SURV	1 x 34	
PAIRAPP ACL	2 x 93	2 x 93
PAIRAPP SURV	1 x 34	
PPD	1 x 105	1 x 277
SAP (Contract Setup)	2 x 95	2 x 100
SAP (Report)	0 x 0	1 x 107
SURV (ATC)	1 x 34	
TIS-B	1 x 34	
URCO	1 x 98	1 x 82
WAKE	1 x 34	

Table 6-15: ATS Message Quantities and Sizes per Instance

Service	Phase 1		Phase 2	
	Uplink Qty x Size (bytes)	Downlink Qty x Size (bytes)	Uplink Qty x Size (bytes)	Downlink Qty x Size (bytes)
AOCDLL	2 x 413	2 x 148	2 x 413	2 x 148
CABINLOG	0 x 0	1 x 477	0 x 0	1 x 477
ENGINE	1 x 88	1 x 727	2 x 88	2 x 727
FLTLOG	0 x 0	2 x177	0 x 0	2 x 177
FLTPLAN	17 x 285	17 x 90	9 x 968	9 x 92
FLTSTAT	0 x 0	1 x 157	0 x 0	1 x 157
FREETEXT	1 x 377	1 x 377	1 x 377	1 x 377
FUEL	0 x 0	3 x127	0 x 0	3 x 127
GATES	1 x 589	0 x 0	1 x 589	0 x 0
LOADSHT	2 x 913	2 x 93	2 x 913	2 x 93
MAINTPR	4 x 133	4 x 133	4 x 233	4 x 233
MAINTRT	5 x 88	5 x 127	5 x 88	5 x 127
NOTAM	3 x 265	2 x 134	4 x 287	2 x 134
OOOI	0 x 0	1 x 117	0 x 0	1 x 117
POSRPT	1 x 88	1 x 338	1 x 88	1 x 338
SWLOAD	2 x 4077	0 x 0	6 x 4077	0 x 0
TECHLOG	1 x 88	1 x 477	1 x 88	1 x 477
UPLIB	4 x 4077	4 x 88	24 x 4077	24 x 88
WXGRAPH	6 x 4246	6 x 93	5 x 21077	6 x 93
WXRT	0 x 0	1 x103	0 x 0	1 x 103
WXTEXT	5 x 680	2 x 103	5 x 680	2 x 103

Table 6-16: AOC Message Quantities and Sizes per Instance

Services	Uplink Qty x Size (bytes)	Downlink Qty x Size (bytes)
NETCONN	2 x 154	2 x 148
NETKEEP	1 x 93	1 x 93

Table 6-17: NET Message Quantities and Sizes per Instance

6.2.2.4 FRS Data Class of Service

This section describes the categories of **communication services**, i.e., classes of service, that may be used to support the **operational services** while meeting performance requirements previously outlined. The COS categories described herein are not prescriptive, as other communication classes or groupings of operational services exist that still meet operational service requirements.

One of the benefits of grouping similar services into a COS category is that the number of items to manage is reduced. COS definition is a useful step in estimating the communication load. With a reduced set of classes, a particular service may not match exactly one class definition. In such a case, the service was placed in the next highest performance class that meets the service requirement.

Because the NET services are required to support ATS and AOC services, they are normally assigned the class of service with the highest priority.

6.2.2.4.1 Assumptions

The following assumptions were used during the definition of service classes.

- It is assumed that NET services have the highest priority, ATS services have the next highest priority and AOC services have the lowest priority.
- The total number of classes per service volume is limited to a maximum of 6. The NET services are allocated 1 class, the ATS services are allocated up to 3 classes, and the AOC services are allocated up to 2 classes. While the number of classes per service volume is limited to 6, a different subset may be used between service volumes; hence, the number of classes in the master list is greater than 6.
- Class categories were chosen to maintain clear boundaries between ATS and AOC services (in order to facilitate separate links for these services, if desired). In addition, air-ground services are kept separate from air-air services, voice services are kept separate from data services, and addressed services are kept separate from broadcast services.
- For air-ground services, it is assumed that latency and priority are drivers for COS categorisation, at least more so than security, integrity, and/or availability requirements. An alternate approach would be to develop classes that differentiate based on availability requirements.
- For air-air services, both latency and availability were discriminators for developing service classes.

6.2.2.4.2 COS Categories

Table 6-18, Table 6-19 and Table 6-20 present the class categories for air-ground addressed data, air-air addressed data, and broadcasted data, respectively.

COS	ET	$TD_{95\text{-}FRS}$	$C_{UIT\text{-}FRS}$	$I_{UCT\text{-}FRS}$	$A_{P\text{-}FRS}$	$A_{U\text{-}FRS}$	Service Type
DG-A	Reserved (rsvd)	9.8	rsvd	5.0E-8	rsvd	rsvd	NET Data
DG-B	1.6	0.74	0.99999992	5.0E-10	0.9999999995	0.99999995	ATS. A-G Data
DG-C	5.0	1.4	0.9996	5.0E-8	0.999995	0.9995	
DG-D	7.8	2.4	0.9996	5.0E-8	0.999995	0.9995	
DG-E	8.0	3.8	0.996	5.0E-6	0.9995	0.9965	
DG-F	12.0	4.7	0.996	5.0E-8	0.9995	0.9965	
DG-G	24.0	9.2	0.996	5.0E-6	0.9995	0.9965	
DG-H	32.0	13.6	0.996	5.0E-6	0.9995	0.9965	
DG-I	57.6	26.5	0.996	5.0E-6	0.9995	0.9965	
DG-J	Not available	13.6	Not available	5.0E-8	0.9995	0.995	AOC A-G Data
DG-K		26.5		5.0E-10	0.9995	0.995	
DG-L		51.7		5.0E-10	0.9995	0.995	

Table 6-18: Air-Ground Addressed COS Categories (Type DG)

COS	ET	$TD_{95\text{-}FRS}$	$C_{UIT\text{-}FRS}$	$I_{UCT\text{-}FRS}$	$A_{P\text{-}FRS}$	$A_{U\text{-}FRS}$	Service Type
DA-A	rsvd	rsvd	rsvd	rsvd	rsvd	rsvd	rsvd
DA-B	7.8	2.4	0.9996	5.0E-8	0.999995	0.9995	AIRSEP

Table 6-19: Air-Air Addressed COS Categories (Type DA)

COS	ET	$TD_{95\text{-}FRS}$	$C_{UIT\text{-}FRS}$	$I_{UCT\text{-}FRS}$	$A_{P\text{-}FRS}$	$A_{U\text{-}FRS}$	Service Type
DB-A	3.2	0.4	0.99996	5.0E-8	0.9995	0.9995	SURV A-A Data
DB-B	4.8	1.2	0.9996	5.0E-8	0.9995	0.9995	
DB-C	8.0	1.2	0.9996	5.0E-8	0.999995	0.9995	
DB-D	3.2	1.2	0.99996	5.0E-8	0.9999975	0.99995	SURV (ATC) TIS-B WAKE
DB-E	8.0	1.2	0.99996	5.0E-8	0.9999975	0.99995	
DB-F	16.0	1.2	0.99996	5.0E-8	0.9999975	0.99995	

Table 6-20: Broadcast COS Categories (Type DB)

6.2.2.4.3 Class Assignments

Table 6-21, Table 6-22, and Table 6-23 contain COS assignments for ATS, AOC and NET services, respectively.

Service	Phase 1					Phase 2				
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA
ACL	DG-E	DG-E	DG-E	DG-I	-	DG-C	DG-C	DG-C	DG-F	DG-C
ACM	DG-E	DG-E	DG-E	DG-I	-	DG-C	DG-C	DG-C	DG-F	DG-D
A-EXEC	-	-	-	-	-	-	DG-B	DG-B	-	-
AIRSEP	-	-	-	-	-	-	-	-	-	DA-B
AIRSEP SURV	-	-	-	-	-	-	-	-	-	DB-C
AMC	DG-E	DG-E	DG-E	DG-I	-	DG-D	DG-D	DG-D	-	DG-G
ARMAND	-	-	DG-G	-	-	-	-	DG-D	-	-
C&P ACL	-	DG-E	DG-E	DG-I	-	-	DG-D	DG-D	DG-F	-
C&P SURV	-	DB-B	DB-B	DB-B	-	-	DB-B	DB-B	DB-B	-
COTRAC	-	-	-	-	-	DG-D	DG-D	DG-D	DG-F	DG-D
D-ALERT	DG-E	DG-E	DG-E	DG-I	-	DG-D	DG-D	DG-D	DG-F	DG-D
D-ATIS	DG-E	DG-E	DG-E	DG-I	-	DG-D	DG-D	DG-D	DG-G	DG-G
DCL	DG-G	-	-	-	-	DG-D	-	-	-	-
D-FLUP	DG-G	-	-	-	-	DG-D	DG-D	DG-D	DG-H	DG-H
DLL	DG-E	DG-E	DG-E	DG-I	-	DG-C	DG-D	DG-D	DG-G	DG-G
D-ORIS	-	DG-E	DG-E	DG-I	-	-	DG-D	DG-D	DG-G	DG-G
D-OTIS	DG-E	DG-E	DG-E	DG-I	-	DG-D	DG-D	DG-D	DG-G	DG-G
D-RVR	DG-E	DG-E	DG-E	DG-I	-	DG-C	DG-C	DG-D	DG-G	DG-G
DSC	-	-	DG-H	DG-I	-	-	-	DG-D	DG-H	DG-G
D-SIG	DG-G	DG-G	-	-	-	DG-F	DG-D	-	-	-
D-SIGMET	DG-E	DG-E	DG-E	DG-I	-	DG-D	DG-D	DG-D	DG-G	DG-G
D-TAXI	DG-E	DG-E	-	-	-	DG-D	DG-D	-	-	-
DYNAV	-	-	-	-	-	-	-	DG-D	DG-G	-
FLIPCY	DG-H	DG-H	DG-H	DG-I	-	DG-D	DG-D	DG-D	DG-F	DG-D
FLIPINT	DG-H	DG-H	DG-H	DG-I	-	DG-D	DG-D	DG-D	DG-F	DG-D
ITP ACL	-	-	-	DG-I	-	-	DG-D	DG-D	DG-F	-
ITP SURV	-	-	-	DB-B	-	-	DB-B	DB-B	DB-B	-
M&S ACL	-	DG-E	DG-E	-	-	-	DG-D	DG-D	DG-F	-
M&S SURV	-	DB-B	DB-B	-	-	-	DB-B	DB-B	DB-B	-
PAIRAPP ACL	-	-	-	-	-	DG-D	DG-D	-	-	-
PAIRAPP SURV	-	-	-	-	-	DB-A	DB-A	-	-	-
PPD	DG-H	DG-H	DG-H	DG-I	-	DG-D	DG-D	DG-D	DG-G	DG-D
SAP	-	DG-E	DG-E	-	-	-	DG-D	DG-D	-	-
SURV (ATC)	DB-D	DB-E	DB-F	DB-F	-	DB-D	DB-E	DB-E	DB-E	DB-E
TIS-B	DB-D	DB-E	DB-F	DB-F	-	-	-	-	-	-
URCO	-	-	-	-	-	DG-D	DG-D	DG-D	DG-F	DG-D
WAKE	DB-D	DB-E	DB-F	-	-	DB-D	DB-E	DB-E	-	-

Table 6-21: ATS COS Assignments

Service	Phase 1 & 2				
	APT	TMA	ENR	ORP	AOA [12]
AOCDLL	DG-J	DG-J	DG-J	DG-K	DG-K
CABINLOG	DG-K	-	-	-	-
ENGINE	DG-K	DG-K	DG-K	DG-L	DG-L
FLTLOG	DG-K	-	-	-	-
FLTPLAN	DG-J	DG-J	DG-J	DG-K	DG-K
FLTSTAT	DG-J	DG-J	DG-J	DG-K	DG-K
FREETXT	DG-K	DG-K	DG-K	DG-L	DG-L
FUEL	DG-K	DG-K	DG-K	DG-L	DG-L
GATES	DG-J	DG-J	DG-J	DG-K	DG-K
LOADSHT	DG-J	DG-J	-	-	-
MAINTPR	DG-J	DG-J	DG-J	DG-K	DG-K
MAINTRT	DG-K	DG-K	DG-K	DG-L	DG-L
NOTAM	DG-K	DG-K	DG-K	DG-L	DG-L
OOOI	DG-J	-	-	-	-
POSRPT	DG-K	DG-K	DG-K	DG-L	DG-L
SWLOAD	DG-K	DG-K	DG-K	DG-L	DG-L
TECHLOG	DG-K	-	-	-	-
UPLIB	DG-K	DG-K	DG-K	DG-L	DG-L
WXGRAPH	DG-J	DG-J	DG-J	DG-K	DG-K
WXRT	DG-J	DG-J	DG-J	DG-K	DG-K
WXTEXT	DG-J	DG-J	DG-J	DG-K	DG-K

Table 6-22: AOC COS Assignments

Service	Phase 1 & 2				
	APT	TMA	ENR	ORP	AOA [13]
NETCONN	DG-A	DG-A	DG-A	DG-A	DG-A
NETKEEP	DG-A	DG-A	DG-A	DG-A	DG-A

Table 6-23: NET COS Assignments

6.2.2.4.4 Class of Service Implications

The following comments apply to the COS service assignments:

[12] The AOA domain is only applicable in Phase 2.
[13] The AOA domain is only applicable in Phase 2.

- The ground network may be common for all domains and it may provide a limited set of priority levels. If a reduced set of classes is required, many more service categories may need to be placed into the next highest performance category. This typically will result in a higher addressed communication load for the FRS.

6.3 Voice Loading Analysis

The voice loading analysis provides estimated seconds of active talk time per hour for the party line service in each of the service volumes. Additional information regarding the number of transmissions per hour is also provided. Only ATS Controller/pilot voice communication is analysed as there is insufficient information to characterise AOC voice communication. The voice loading associated with broadcast channels such as for ATIS, VOLMET, and AWOS is 100%.

6.3.1 Methodology

The estimated seconds per hour of active Push to Talk (PTT) time and the instance information is developed using the following steps:

- A survey of existing voice studies was conducted to determine the average number of transmissions per aircraft (#tx/ac) per service volume and the average duration of each transmission (#sec/tx) [19]. For comparison with data communications loading, the number of instances per aircraft (#instances/ac) is also estimated. An instance contains a sequence of related voice transmissions.
- The total number of seconds of voice per hour per service volume (#sec/hr/SV) is calculated using the metrics from the voice study survey in tandem with PIAC, flight times per service volume (SV), data communications equipage rates, and voice/data utilisation rates presented in Section 6.2.1.4. The loading analysis uses an average flight time for volumes that specify both arrival and departure aircraft durations.
- The total number of seconds of voice per hour per position (#sec/hr/position) is calculated from the number of positions per service volume (#positions/SV). In addition, the occupancy and number of transmissions per hour per position (#tx/hr/position) is calculated.

Unlike the other services volumes, the APT is comprised of multiple types of voice positions, i.e., ramp/clearance, ground, and tower. High-density airports may contain multiple instances of a particular type of position, e.g., two ground positions. Low-density airports do not require all three position types and may combine the ramp/clearance and ground positions. Since the referenced voice studies only provide data for ground and tower positions only these two positions are considered in the voice loading analysis. Accordingly, the PIAC and flight times used here correspond to these two positions. Further, it is assumed that for the high density airport, two ground positions and one tower position are required to handle the PIAC traffic. The FRS would need to support separate party-line channels for each position.

6.3.2 ATS Voice Transmission Characteristics

The voice transmission characteristics per service volume are based on a survey of studies [19] that evaluate both typical and worst-case conditions for various airspace domains assuming limited or non-existent use of data communications. The ORP service volume values were estimated because of limited or non-existent reference data. The number of seconds per aircraft includes only active PTT time. The number of instances per aircraft in each service volume has been calculated by dividing the number of transmissions by the estimated number of transmissions required per instance. The APT number of transmissions and transmission duration are for ground and tower positions only.

Parameter	APT	TMA	ENR	ORP
#tx/ac	16.5	6.8	8.8	3
#sec/tx	3	2.8	3.3	3.3
#sec/ac	49.5	19.0	29.0	9.9
#tx/instance	2	2	2.8	2.8
#instances/ac	8.3	3.4	3.1	1.1

Table 6-24: ATS Voice Transmission Characteristics per Service Volume

6.3.3 Service Volume Results

Table 6-25 and Table 6-26 provide the estimated ATS voice communication load for Phase 1 and Phase 2, respectively. Explanatory material on the tables is provided immediately after the tables.

PHASE 1	APT		TMA		ENR			ORP	
	HD	LD	HD	LD	NAS -HD	ECAC-HD	LD	HD	LD
#tx/ac	16.5	16.5	6.8	6.8	8.8	8.8	8.8	3	3
#sec/tx	3	3	2.8	2.8	3.3	3.3	3.3	3.3	3.3
#sec/ac	49.5	49.5	19.0	19.0	29.0	29.0	29.0	9.9	9.9
PIAC	66	8	16	14	41	24	24	10	5
% ac (voice only ac)	25%	25%	25%	25%	25%	25%	25%	20%	20%
% voice util (data communications ac)	60%	60%	60%	60%	40%	40%	40%	5%	5%
flight duration/SV (#sec)	870	450	334	519	675	675	900	2550	2550
#sec/hr/ac	205	396	206	132	155	155	116	14	14
#sec/hr/SV (voice only ac)	3380	792	822	462	1588	929	697	28	14
#sec/hr/SV (data communications ac)	6083	1426	1480	832	1905	1115	836	6	3
#sec/hr/SV (total)	9463	2218	2302	1294	3493	2044	1533	34	17
#positions/SV	3	2	1	1	1	1	1	1	1
#sec/hr/position	3154	1109	2302	1294	3493	2044	1533	34	17
# tx/hr/position	1051	739	822	462	1058	620	465	10	5
occupancy/position	88%	31%	64%	36%	97%	57%	43%	1%	0%

Table 6-25: Phase 1 Voice Communications Load

PHASE 2	APT		TMA		ENR			ORP	
	HD	LD	HD	LD	NAS -HD	ECAC-HD	LD	HD	LD
#tx/ac	16.5	16.5	6.8	6.8	8.8	8.8	8.8	3	3
#sec/tx	3	3	2.8	2.8	3.3	3.3	3.3	3.3	3.3
#sec/ac	49.5	49.5	19.0	19.0	29.0	29.0	29.0	9.9	9.9
PIAC	96	12	44	39	95	45	59	34	18
% ac (voice only ac)	15%	15%	15%	15%	0%	0%	0%	0%	0%
% voice util (data communications ac)	15%	15%	15%	15%	5%	5%	5%	1%	1%
flight duration/SV (#sec)	870	450	267	415	984	984	1230	3825	3825
#sec/hr/ac	205	396	257	165	106	106	85	9	9
#sec/hr/SV (voice only ac)	2950	713	1698	966	0	0	0	0	0
#sec/hr/SV (data communications ac)	2507	606	1443	821	505	239	251	3	2
#sec/hr/SV (total)	5457	1319	3140	1788	505	239	251	3	2
#positions/SV	3	2	1	1	1	1	1	1	1
#sec/hr/position	1819	659	3140	1788	505	239	251	3	2
# tx/hr/position	606	440	1122	638	153	72	76	1	1
occupancy/position	51%	18%	87%	50%	14%	7%	7%	0%	0%

Table 6-26: Phase 2 Voice Communications Load

The airport PIACs and flight duration above reflect the sum of the ground and tower positions. The resulting #sec/hr/SV values are for combined ground and tower positions.

The following notes provide information on the calculations used in the tables above.

- The #sec/hr/ac is calculated by dividing the #sec/ac by the flight duration.
- The #sec/hr/SV (voice only ac) is calculated by multiplying the #sec/hr/ac times the voice only aircraft count (i.e., PIAC x voice only percentage).
- The #sec/hr/SV (voice utilisation by data communications ac) figures are calculated by multiplying #sec/hr/ac times the data communications aircraft count times the voice utilisation percentage.
- The total #sec/hr/SV is the sum of the previous two calculations.
- The #tx/hr/position by dividing the total #sec/hr/position by the #sec/tx.

6.3.4 Analysis of Results

For Phase 1, the occupancy numbers are large compared to typical occupancy rates for some domains. This difference can be primarily attributed to the use of PIAC data instead of average aircraft counts (or aircraft per hour figures). Nonetheless, it is useful to look at PIAC-based loading to get a sense of worst case conditions especially when those worst case conditions are close to actual peak conditions. For example in the APT domain, the Los Angeles Airport [18] measured occupancy rates of 68% for a peak activity period spanning 1 hour. Note that if 4 positions were assumed for the APT, i.e., two ground and two towers, the occupancy rate would drop to 66%. In the TMA domain, the New York TRACON arrival sectors have experienced 81% occupancy over a period of 1 hour [45]. In the ENR domain, the Vocalise study [35] has shown occupation rates over 77% over a 5 minute period and near 60% over a 15 minute period.

For Phase 2, the data communications equipage and utilization rates are key factors that will allow the PIAC to grow while still allowing the voice channel to support the service volume.

6.4 Addressed Data Loading Analysis

The addressed communication loading analysis provides an estimate of the communication load for addressed data communications. Separate and combined communication loads are estimated for ATS and AOC traffic. Separate and combined communication loads are estimated for uplink (UL) and downlink (DL) traffic. In addition, results are provided for all aircraft in the service volume and for a single aircraft using a dedicated channel.

The varied aggregations provide flexibility in the assessment of potential FRS technologies.

Note: The air-air addressed portion of the AIRSEP service has been excluded from the addressed communication loading analysis, because it is the only addressed service that is not air-ground. It instead has been included with the other air-air services in the broadcast communication loading. See Section 6.5 for details. Thus, this addressed loading analysis is an ***air-ground*** *addressed communication loading analysis.*

6.4.1 Methodology

The addressed communication loading analysis uses a non-preemptive queuing model to estimate addressed communication loads. A two step process was used to develop the addressed communication loading estimate.

- **Traffic Model:** A traffic model was developed to use as an input to the queuing model. The service instances (see Section 6.2.1.2), service volume flight durations (see Section 6.2.1.3) and service volume PIACs (see Section 6.2.1.5.1 and 6.2.1.5.3) were used to derive message arrival rates. The addressed services were identified (see Section 6.2.2.1 and 6.2.2.2). Each service was assigned to a queue in accordance with the FRS COS assignments (see Section 6.2.2.4). The individual service arrival rates and message sizes (see Section 6.2.2.3) were used to calculate the queue message arrival rates and sizes.
- **Queuing Model:** A non-pre-emptive priority queuing model was used to develop the capacity requirements. In the model, messages in higher priority

queues (e.g., classes of service) are serviced before messages in lower priority queues. Once the server in the model has begun to transmit a message from any particular priority queue, it continues to transmit the message even if a higher priority message should arrive during transmission. Given a selected information transfer rate, the queuing model predicts the 95th percentile delay for the largest service message within each queue. The model is run iteratively until all queues meet the required latency performance.

Details of the model and the methodology to employ it, can be found at Appendix C.

Note: All of the results in this section assume 100% data equipage within the service volume in order to obtain a reasonable worst case communication load.

While the model produces detailed results, these detailed figures imply a level of precision that is not appropriate given the approximate nature of the many of the input assumptions. Hence, all results have been rounded.

6.4.2 Service Volume Results

Table 6-27 provides the estimated addressed communication load for high density and low density Phase 1 service volumes within each airspace domain. Table 6-28 and Table 6-29 provide the results for Phase 2 service volumes with and without the A-EXEC service, respectively.

PHASE 1		**APT SV**		**TMA SV**		**ENR SV**			**ORP SV**		**AOA**
		HD	**LD**	**HD**	**LD**	**HD EU**	**HD U.S.**	**LD**	**HD**	**LD**	
Separate ATS	**UL**	5	4	4	4	4	4	4	1	1	-
	DL	8	7	8	8	7	8	7	3	3	-
	UL&DL	9	7	8	8	8	8	8	3	3	-
Separate AOC	**UL**	20	8	2	2	15	15	15	5	5	-
	DL	4	1	1	1	1	2	1	1	0.4	-
	UL&DL	20	8	2	2	15	15	15	5	5	-
Combined ATS&AOC	**UL**	20	8	4	4	15	15	15	5	5	-
	DL	8	7	8	8	7	8	7	3	3	-
	UL&DL	30	8	8	8	15	20	15	5	5	-

Table 6-27: Phase 1 Addressed Communication Load (kilobits per second [kbps])

PHASE 2		APT SV		TMA SV		ENR SV			ORP SV		AOA
		HD	LD	HD	LD	HD EU	HD U.S.	LD	HD	LD	
Separate ATS	UL	30	20	30	30	30	30	30	15	15	20
	DL	30	30	30	30	30	30	30	20	20	30
	UL&DL	40	30	40	40	30	40	30	20	20	30
Separate AOC	UL	150	40	2	2	60	100	70	30	30	70
	DL	7	2	3	3	2	3	2	1	1	2
	UL&DL	200	40	4	4	60	150	80	30	30	80
Combined ATS&AOC	UL	150	40	30	30	150	200	150	40	30	100
	DL	30	30	30	30	30	30	30	20	20	30
	UL&DL	200	40	40	40	150	200	150	40	30	100

Table 6-28: Phase 2 Addressed Communication Load (kbps) – with A-EXEC

PHASE 2		APT SV		TMA SV		ENR SV			ORP SV		AOA
		HD	LD	HD	LD	HD EU	HD U.S.	LD	HD	LD	
Separate ATS	UL	30	20	30	30	30	30	30	15	15	20
	DL	30	30	30	30	30	30	30	20	20	30
	UL&DL	40	30	40	40	30	40	30	20	20	30
Separate AOC	UL	150	40	2	2	60	100	70	30	30	70
	DL	7	2	3	3	2	3	2	1	1	2
	UL&DL	200	40	4	4	60	150	80	30	30	80
Combined ATS&AOC	UL	150	40	30	30	80	150	90	40	30	100
	DL	30	30	30	30	30	30	30	20	20	30
	UL&DL	200	40	40	40	80	150	90	40	30	100

Table 6-29: Phase 2 Addressed Communication Load (kbps) – without A-EXEC

6.4.3 Single Aircraft Results

Table 6-32 provides the estimated Phase 1 addressed communication load for a single aircraft assuming the use of an individual, dedicated channel. Table 6-31 and Table 6-30 provide the results for Phase 2 with and without the A-EXEC service, respectively.

PHASE 1		APT SV Dep	APT SV Arr	TMA SV Dep	TMA SV Arr	ENR SV	ORP SV
Separate ATS	**UL**	4	1	1	4	4	1
	DL	7	7	7	7	7	3
	UL&DL	7	7	7	7	7	3
Separate AOC	**UL**	8	0.3	0.3	2	8	4
	DL	1	1	1	1	1	0.4
	UL&DL	8	1	1	2	8	4
Combined ATS&AOC	**UL**	8	1	1	4	8	4
	DL	7	7	7	7	7	3
	UL&DL	8	7	7	7	8	4

Table 6-30: Phase 1 Addressed Communication Load (kbps) – Single Aircraft

PHASE 2		APT SV Dep	APT SV Arr	TMA SV Dep	TMA SV Arr	ENR SV	ORP SV	AOA
Separate ATS	**UL**	20	3	20	20	20	15	20
	DL	30	10	30	30	30	20	30
	UL&DL	30	10	30	30	30	20	30
Separate AOC	**UL**	40	0.3	0.3	2	40	20	20
	DL	1	1	1	1	1	0.4	0.4
	UL&DL	40	1	1	2	40	20	20
Combined ATS&AOC	**UL**	40	3	20	20	40	20	30
	DL	30	10	30	30	30	20	30
	UL&DL	40	10	30	30	40	20	40

Table 6-31: Phase 2 Addressed Communication Load (kbps) – Single Aircraft with A-EXEC

PHASE 2		APT SV Dep	APT SV Arr	TMA SV Dep	TMA SV Arr	ENR SV	ORP SV	AOA
Separate ATS	UL	20	3	20	20	20	15	20
	DL	30	10	30	30	30	20	30
	UL&DL	30	10	30	30	30	20	30
Separate AOC	UL	40	0.3	0.3	2	40	20	20
	DL	1	1	1	1	1	0.4	0.4
	UL&DL	40	1	1	2	40	20	20
Combined ATS&AOC	UL	40	3	20	20	40	20	30
	DL	30	10	30	30	30	20	30
	UL&DL	40	10	30	30	40	20	40

Table 6-32: Phase 2 Addressed Communication Load (kbps) – Single Aircraft without A-EXEC

6.4.4 Analysis of Results

6.4.4.1 General Comments

Following are general comments data loading analysis:

- **Model Validation:** Although the model used is based on reasonable assumptions and formulas, both the model and its application in this loading analysis need to be validated.

  Note: The model has iterated since Version 2.0 of the COCR. The two changes are described in Appendix C. While the iterated model provides the best estimate available of the required information transfer rate, it is not a detailed simulation based on a particular implementation. The model is used for estimating purposes only and actual loading results may vary.

- **Data Compression Impacts:** The results are based on the size of messages arriving at the FRS boundary. Consequently compression techniques that could be employed to reduce the number of bits sent over the physical link have not been taken into account as the COCR is technology independent.
- **Collisions and Media Access Delays:** The model does not include RF collisions, retransmissions due to bit errors, or RF media access delays (e.g., waiting for the next available slot).
- **bps per Aircraft:** An important conclusion of the loading work done thus far is that the increase in transfer rate requirements is not linear with the increase in aircraft; hence, **one cannot reasonably use a bits per second (bps)/aircraft number in tandem with aircraft count to predict required bit rates.** Many of the low density and high density service volumes have the same estimated capacity requirement. The reason for the non-linearity resides in the projected occupancy of the link. **In many cases, the message latency requirements drive the information transfer rate rather than the quantity of information.** Thus, the link may not always be actively transmitting messages.

- **Message Sizes, Quantities and Latencies:** It should be restated that the results rely on a number of input assumptions (e.g., message sizes and number of messages per transaction) and use performance figures based on a high level operational hazard assessment. Loading results are sensitive to these assumptions (refer to Section 6.2 for a list of assumptions). The one-way latency requirements were applied to each one-way message. Future work is required to complete detailed safety and performance work for each individual service and to refine message sizes and/or sequences in greater detail.

  Note: While Version 2.0 has incorporated additional safety and performance information, future standards work will continue to refine message sizes and/or sequences.

- **Driving COS Category:** In all cases, one of the several queues (i.e., classes of services) in the aggregate flow drives the required information transfer rate. In other words, only one of the categories has a 95% predicted delay that is equivalent to the COS category delay requirement. The other COS categories have predicted delays that are less than the COS category delay requirement. Further, it is not necessarily the highest performance (priority) category that ends up being the driving COS category. Sometimes the middle and low priority queues are the driving queues because the message size to delay ratios may be larger for these queues. Typically, changes to non-driving queues have lower impact and result in less significant changes in the required information transfer rates. It is also interesting to note that while the system/network service messages were assigned the highest priority, in general, the associated queue (Type DG-A) was not identified as the driving COS queue category.

- **COS Category Definitions:** It should be noted that alternative COS category definitions (and the resulting difference in placement of operational services) may significantly impact information transfer rate requirements. For example, a reduction in the number of categories in the master list may result in the up-levelling of a number of services which, in turn, may increase the required information transfer rate.

- **Message Segmentation:** The assumed message sizes were not adjusted to consider packet size limitations common with networks; that is, message segmentation was not assumed. It is anticipated that the results might be somewhat affected if this was taken into account. For example, if a large lower priority message was segmented, it would allow a higher priority message to be inserted in the data flow before the transmission of the lower priority message is completed.

6.4.4.2 Specific Comments

The following are comments that apply to one or more of the results in the above tables:

- **A-EXEC Service:** The A-EXEC Service is a performance driver in the Phase 2 ENR service volume.

  Note: The use of rounding and changes in the model to use maximum message sizes has reduced the difference in Version 2.0 between results with and *without A-EXEC. Notwithstanding, the A-EXEC service is still a performance driver in the Phase 2 ENR service volume.*

- **Capacity in Phase 2:** The increase in capacity requirements in Phase 2 for the Airport Domain can be attributed in part to increased message sizes and reduced latencies.

6.5 Broadcast Data Loading Analysis

The broadcast data loading analysis provides an estimate of the needed information transfer rate within a defined transmission volume.

Note: The addressed portion of the AIRSEP service has been included in the broadcast communication loading analysis. It has been assumed that this addressed operational service is transmitted using broadcast communication service, e.g., an addressed message is provided to the FRS, the FRS broadcasts the addressed message, and only the FRS addressee receives/processes the message.

Broadcast ranges are based on operational requirements for data transfer between users. Air-air transfers have shorter range requirements than air-ground transfers. For example, the C&P SURV range in the ENR domain is 100 NM and the ATC SURV range is 200 NM in the same domain. Data transfers for air-ground applications can be supported by a set of networked ground transmitters/receivers; so, the aircraft transmission doesn't necessarily need to meet the full range.

The objective of the loading analysis is to estimate the required **information transfer rate** that must be supported by the FRS. As such, it does not consider the impacts of transmission collisions (common with 'unorganised' broadcast technology) or media access delays or scheduling overhead (common with 'organised' shared-media access technologies).

A simple model was used to develop the capacity requirements. Only worst case transmission volume densities are evaluated.

The following sections provide a brief description of the methodology, loading analysis results, and an analysis of the results.

6.5.1 Methodology

The estimated **information transfer rate** is for each broadcast service is calculated by multiplying the PIAC (see Section 6.2.1.5.2) by the message size (see Section 6.2.2.3) and dividing the result by the FRS latency requirement (see Section 6.2.2.4). Results are provided for domain-based transmission volumes and fixed range transmission volumes (see Section 6.2.1.1.2).

For the APR, TMA and ENR domains in Phase 1, the totals for the domain-based transmission volumes are the sum of the SURV and TIS-B loads. For same domains in Phase 2, the totals are the sum of the SURV, WAKE, and PAIRAPP totals. The C&P, ITP, M&S SURV broadcast loads are excluded from the totals because they are redundant with the SURV broadcasts.

6.5.2 Transmission Volume Results

Table 6-33 and Table 6-34 provide the Phase 1 results for the domain-based and fixed range transmission volumes, respectively. Table 6-35 and Table 6-36 provide the Phase 2 results.

Services	Update rate (s)					Range (NM)					Latency FRS (s) TD[95]					PIAC					Msg Size (bytes)	Information Transfer Rate (kbps)				
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	ALL	APT	TMA	ENR	ORP	AOA
C&P SURV	-	-	3	3	-		-	100	100	-	-	-	1.2	1.2	-	-	-	250	3	-	34	-	-	57	0.7	-
ITP SURV	-	-	-	3	-		-	-	100	-	-	-	-	1.2	-	-	-	-	3	-	34	-	-	-	0.7	-
M&S SURV	-	3	3	-	-		60	100	-	-	-	1.2	1.2	-	-	-	125	250	-	-	34	-	28	57	-	-
PAIRAPP SURV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AIRSEP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AIRSEP SURV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SURV	2	5	10	10	-	5	100	200	200	-	0.4	1.2	1.2	1.2	-	232	300	850	10	-	34	158	68	193	2.3	-
TIS-B (note 1)	2	5	10	-	-	5	100	200	-	-	0.4	1.2	1.2	-	-	232	300	850	-	-	34	158	68	193	-	-
WAKE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL (kbps)																						**316**	**136**	**386**	**2.3**	**-**

Note 1 – TIS-B is a special case in that the age of the surveillance data could be older than the update rate.

Table 6-33: Phase 1 Broadcast Information Transfer Rate – Separate Domains

Services	Update rate (s)			Range (NM)			Latency FRS (s) TD[95]			PIAC			Msg Size (bytes)	Information Transfer Rate (kbps)			TOTAL
	APT	TMA	ENR	APT	TMA	ENR	APT	TMA	ENR	APT	TMA	ENR	ALL	APT	TMA	ENR	TOTAL
Range 100 NM	2	5	10	100	100	100	0.4	1.2	1.2	475	300	250	68	646	136	113	**895**
Range 150 NM	2	5	10	100	100	100	0.4	1.2	1.2	700	600	500	68	952	272	227	**1,451**

Table 6-34: Phase 1 Broadcast Information Transfer Rate – Fixed Range

Services	Update rate (s)					Range (NM)					Latency FRS (s) TD^{95}					PIAC					Msg Size bytes	Information Transfer Rate (kbps)				
	APT	**TMA**	**ENR**	**ORP**	**AOA**	**APT**	**TMA**	**ENR**	**ORP**	**AOA**	**APT**	**TMA**	**ENR**	**ORP**	**AOA**	**APT**	**TMA**	**ENR**	**ORP**	**AOA**	**ALL**	**APT**	**TMA**	**ENR**	**ORP**	**AOA**
C&P SURV	-	-	3	3	-		-	100	100	-	-	-	1.2	1.2	-	-	-	320	14	-	34	-	-	73	3.2	-
ITP SURV	-	3	3	3	-		60	100	100	-	-	1.2	1.2	1.2	-	-	160	320	14	-	34	-	36	73	3.2	-
M&S SURV	-	3	3	-	-		60	100	-	-	-	1.2	1.2	-	-	-	160	320	-	-	34	-	36	73	-	-
PAIRAPP SURV	2	2	-	-	-	5	60	-	-	-	0.4	0.4	-	-	-	4	10	-	-	-	-	3	7	-	-	-
AIRSEP	-	-	-	-	-	-	-	-	-	100	-	-	-	-	2.4	-	-	-	-	12	497	-	-	-	-	20
AIRSEP SURV	-	-	-	-	5	-	-	-	-	100	-	-	-	-	1.2	-	-	-	-	36	34	-	-	-	-	8
SURV	2	5	5	5	-	5	100	200	200	-	0.4	1.2	1.2	1.2	-	322	400	1100	34	-	34	219	91	249	7.7	-
TIS-B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAKE	2	5	5	-	-	5	100	200	-	-	0.4	0.4	1.2	-	-	26	400	1100		-	34	18	272	249	-	-
TOTAL (kbps)																						**239**	**370**	**498**	**7.7**	**28**

Table 6-35: Phase 2 Broadcast Information Transfer Rate – Separate Domains

Services	Update rate (s)			Range (NM)			Latency FRS (s) TD^{95}			PIAC			Msg Size bytes	Information Transfer Rate (kbps)			TOTAL (kbps)
	APT	**TMA**	**ENR**	**APT**	**TMA**	**ENR**	**APT**	**TMA**	**ENR**	**APT**	**TMA**	**ENR**	**ALL**	**APT**	**TMA**	**ENR**	
Range 100 NM	2	5	10	100	100	100	0.4	0.4	1.2	600	400	320	68	816	544	145	**1,407**
Range 150 NM	2	5	10	100	100	100	0.4	0.4	1.2	900	800	640	68	1,224	1,088	290	**2,602**

Table 6-36: Phase 2 Broadcast Information Transfer Rate – Fixed Range

6.5.3 Analysis of Results

As noted in the introductory paragraphs, the analysis looks at potential **information transfer rates** and thus does not include the impacts of transmission collisions, media access delays and/or scheduling/message overhead. For UAT, the message overhead includes synchronization and forward error correction (FEC) bits that would increase the overall message size by 76%. For 'unorganised' broadcast technologies, the collision rate increases with increasing message transmission densities. For these technologies, increasing transmission rates are met with diminishing returns. It is reasonable to assume that for these technologies the required RF transmission rates would, at least, need to be double that of the values reflected in the tables above for the higher message density transmission volumes.

7 CONCLUSIONS

7.1 Overall

This final version of the COCR has been developed primarily to estimate the requirements for a future communication system and to enable selection of supporting communications technologies. To achieve this, a requirements-driven approach was taken to assess air-ground and air-air data and voice ATS and AOC communications i.e., safety and regularity of flight communications needed to support future concepts. Several rounds of stakeholder consultations were conducted to ensure agreement on the process which was followed. Wide distribution of earlier versions of the COCR was provided via national and international forums. The technical requirements for a Future Radio System were determined from the operational requirements, independent from any specific technology. This approach ensures that the communications requirements were based on the needs rather than being driven by technology.

Two main phases of ATM developments were considered. The first phase (Phase 1) represents an increasing use of data communications, but is essentially similar to current tactical management of aircraft. Concepts in Phase 2 represent a paradigm shift towards more intervention by exception principles. It includes use of trajectory management, greater information exchange between aircraft and ground systems to achieve better airspace utilisation and user preferred trajectories. In addition, autonomous operations take place in some parts of the airspace. The concepts were drawn from the ICAO and regional implementation plans. In particular, concepts emerging from SESAR in Europe and NextGen in the United States were included where information was available.

Having identified the concepts and underlying service requirements, the amount of communication traffic generated in representative operational volumes was then calculated. As part of this process, it was decided to define volumes of airspace in which the services were required. Service Domains used were airport, terminal manuevering area, en route (continental), oceanic, remote, polar and autonomous operations areas. Definitions of these airspace types are given in the document. Safety and information security requirements were undertaken as part of the determining the requirements. The growth in traffic was also taken into account using prediction tools.

Throughout the period considered voice communication was considered to be available at all times. However the general trend is that voice will reduce and only be used where tactical ATM invention is required or for unusual or emergency situations.

7.2 Global Applicability

The regional applicability of the concepts described in the two phases will be dependent on airspace capacity limitations. Consequently, the introduction of all or some of the services described in each phase will depend on the density of traffic and associated business cases.

7.3 Results

The document contains a range of parameters on which the suitability of communication systems can be assessed. They include performance requirements such as continuity, integrity and availability, safety and security requirements and capacity.

A model was developed to determine the required capacity of the FRS to handle the traffic generated by the ATS and AOC services. A number of options for the queuing model were considered and the final option implemented used a single non-pre-emptive queue supporting ATS and AOC. ATS and AOC requirements were also determined independently. Other ways of using the raw data identified in this document can be envisaged and may be useful when reviewing specific technologies as part of the assessment process. Worse case conditions were assumed so that the requirements were not underestimated.

The most stringent FRS allocated data requirements are highlighted in Table 7-1.

Service & Phase	**Service Type**	**Confidentiality**	**Latency (sec)**					**Integrity FRS**	**Availability Of Provision FRS**
			APT	**TMA**	**ENR**	**ORP**	**AOA**		
ATS Phase 1	Broadcast	Medium	0.4	1.2	1.2	1.2	-	5.0E-8	0.9999975
	Addressed	Medium	3.8	3.8	3.8	26.5	-	5.0E-6	0.9995
ATS Phase 2	Broadcast	Medium	0.4	1.2	1.2	1.2	1.2	5.0E-8	0.9999975
	Addressed	Medium	1.4	0.74	0.74	5.9	1.4	5.0E-10	0.9999999995
AOC 1+2	Addressed	Medium	13.60	13.60	13.60	26.50	26.5	5.0E-10	0.9995

Table 7-1: Most Stringent FRS Allocated Data Requirements

The A-EXEC service is a driving service. It has the fastest latency requirement and a very high availability requirement.

A model was developed to determine the required capacity of the FRS to handle the traffic generated by the ATS and AOC services. A number of options for the queuing model were considered, and the final option implemented used a single non-pre-emptive queue supporting ATS and AOC. ATS and AOC requirements were also determined independently. Other ways of using the raw data identified in this document can be envisaged and may be useful when reviewing specific technologies as part of the assessment process. Worse case conditions were assumed so that the requirements were not underestimated.

Addressed Communication Load		APT SV		TMA SV		ENR SV			ORP SV		AOA
		HD	LD	HD	LD	HD EU	HD U.S.	LD	HD	LD	
ATS&AOC UL&DL	Phase 1	30	8	8	8	15	20	15	5	5	-
	Phase 2	200	40	40	40	150	200	150	40	30	100

Table 7-2: Most Stringent FRS Addressed Communication Load (kbps)

In Phase 2, the reduced latencies and large message sizes for new services (e.g. COTRAC) have resulted in significantly larger communication load.

Some sensitivity analysis was carried out on the results and it was noted that the capacity requirements do not increase linearly with aircraft density. In some cases, the latency had the greatest effect on capacity. Under these conditions not all the capacity was used therefore doubling the aircraft to be supported did not double the capacity requirements.

7.4 Observations

7.4.1 Safety assessment methodology

Considerable effort was undertaken in carrying out safety assessments of the new services in the context of the two phases to determine the effects on the FRS. The COCR team reviewed and applied existing safety assessments done by other organisations to determine the requirements on the FRS. The task was therefore made more difficult due to the need to understand the different approaches adopted.

7.4.2 Advanced ATS Services

In reviewing future concepts, some very advanced services were identified which Stakeholders believed would be implemented within the timeframe of the COCR. One such service is A-EXEC. During the safety assessment, it became apparent that the service requires extremely high latency, integrity and availability requirements. These requirements make evolution to the environment defined for its use subject to further consideration. Of particular concern is automatic execution of flight manoeuvres without pilot involvement.

7.4.3 AOC Services

The COCR team acquired as much information as possible on the future plans for use of AOC services. The services identified were understood to be those that commercial airspace users are either using or plan to use in the future. If a major expansion of AOC services takes place, this could considerably increase the communication requirements.

7.5 Areas for Further Consideration

The following areas were identified for further consideration.

- Refinement of the safety assessment process.

- Performance assessment methodology against operational use e.g., a given instance of the ACL service could include several one-way transits needing to take place within the RCP to close the operational uplink and downlink.
- During the timeframe of the FCS, future concepts used to derive the FCS requirements were still evolving. Re-assessment of the final versions of those concepts may change the requirements that a given technology must support.
- The results of this study highlight the need for continuing collaboration between the parties.
- Update of Peak Instantaneous Aircraft Counts allowing for new traffic demand models that have come into existence since this work was started, especially in the TMA domain.
- Refinements in the operational scenarios to more fully include UAS, VLJ, and General Aviation aircraft and their needs in the timeframes discussed.
- Refinement of the voice requirements and subsequent voice loading analysis.
- During the study, AOC communication requirements were developed using the best information available. This form of communication is known to have progressed significantly during the study and should be reassessed.

APPENDICES

Appendix A STATFOR AND SAAM OVERVIEW

A.1 Description of the Air Traffic Statistics and Forecast Service

The Air Traffic Statistics and Forecast (STATFOR) service was established by the EUROCONTROL Agency and has been active since 1967. The objective of the STATFOR service is to provide statistics and forecasts on air traffic in Europe and to monitor and analyse the evolution of the Air Transport Industry.

The STATFOR service of statistics and forecasts is discussed and reviewed by the STATFOR User Group, a body of European forecasting and statistics experts that meets regularly. The terms of reference of the User Group include methodological and practical aspects of statistics and forecasting as well as an exchange of views and information on the current and possible future situation of air traffic, and on activities in National Administrations, International Organizations and elsewhere in the field of statistics and forecasting.

Currently, STATFOR's two main products are monthly statistics, and an annual medium-term forecast.

A.2 Description of the System for Traffic Assignment and Analysis at a Macroscopic Level (SAAM)

SAAM is an integrated system for wide or local design evaluation, analysis, and presentation of Air Traffic Airspace/TMA scenarios.

A.2.1 Background

EUROCONTROL develops and operates a set of tools in order to assess quantitative information in support of development at Europe's airports, on air routes and the airspace system. SAAM is being used in the context of Airspace Management and Navigation activities to perform strategic traffic flow organisation, route network and airspace optimisation, analysis and presentation. These features support the development of the EUROCONTROL Airspace Strategy for the ECAC states.

SAAM can operate on an area the size of ECAC or at the detailed level of an airport, and is able to process a large quantity of data: hundreds of sectors, millions of cells, several days of traffic. It can be used for preliminary surveys, for testing and analysing various options and for preparing a scenario that can be exported to fast-time or realtime simulators. Its powerful "what if" functions associated with presentational capabilities make SAAM an ideal tool for understanding, experimenting, evaluating and presenting European Airspace proposals and future ATC concepts.

A.2.2 Modelling

Airspace structure design and the processing of traffic trajectories are fully mastered and linked together in SAAM. Users can create/change/design both air traffic route networks and airspace volumes. At any time full 4-D trajectories can be generated (based on traffic demand, route network, aircraft performance) and intersected with airspace volumes. By default, SAAM will choose the best trajectory option (shortest path and optimal profile performance), but operational rules can be applied such as flight level constraints (arrival, departure, cruising) and/or reserved or restricted route network segments.

In order to help optimise airspace structures, the user can request the traffic demand be optimally and automatically distributed on the structure at the lowest cost, while respecting operational rules, thus revealing structural weaknesses of airspace areas. This function makes use of advanced linear programming techniques, embedded in the SOP model and developed in the EUROCONTROL Airspace Management and Navigation (AMN) Unit. SIDs and STARs can be portrayed for different cases, possibly with terrain data to help understand and improve TMA organisation.

A.2.3 Analysis

Different sources of data can be selected for analysis and comparisons: Central Flow Management Unit (CFMU) flight plan, imported radar data, or simply the data coming out from the SAAM modelling tools.

Many queries can be combined and applied on the 4-D traffic trajectories. For instance, the user can request flight trajectories based on departures, arrivals, route points, companies, sectors crossed, aircraft type, etc.

Various analyses can be performed on loaded airspace structures. The number of flights on route network points, route network segments, airspace volume and three dimensional (3-D) density cells can be filtered and displayed accordingly. Graphs showing variations and comparisons of airspace load, entry rate, and conflict, for each hour of the day are easily produced. In the same manner, Controller workload graphs can be provided rapidly using a validated analytical formula. Capacity figures for newly designed sectors can be advantageously derived using the analytical formulas.

Route length extension, fuel consumption, delays, route charges, etc., can be launched independently, and results can be summarised and mixed to give a global economic indicator of a scenario.

A.2.4 Visualization/Presentation

The importance of visually pinpointing problems and graphically presenting possible solutions was recognised from the beginning. Therefore, SAAM is entirely built on a 2-D/3-D/4-D Geographical Information System (GIS) with the possibility of generating time-based animations. To add more realism, SAAM can also manage and generate stereo information (with specific hardware-like stereo glasses).

All modelling and analysis activities are integrated in this GIS platform and fully benefit from the 3-D visualisation, animation and stereo. For instance a user can design a specific airspace of interest in 3-D to check interaction while aircraft are flying on their 3-D trajectories. Images/animations are interactively panned, zoomed, and rotated with the mouse. The camera location and/or “look at” point can be moved or linked to a flying object.

Objects such as aircraft, airspace volumes, points or lines, can be moved, set on/off, or have their graphical attributes (e.g., colour or size) smoothly changed based on time events managed through the animations. For example, this feature is commonly used to demonstrate the benefits of Flexible Use of Airspace (FUA) project. Several 3-D aircraft models are available and can be imported from the classical “3ds” format.

Users can add titles and bitmaps to their design. Pictures/animations can be grouped into a SAAM presentation file that can be run manually or in standalone mode. If preferred, a SAAM presentation can be recorded in a standard “avi” movie file.

Appendix B MID LEVEL MODEL DESCRIPTION

B.1 Introduction

Modelling is the technique of building an imitative representation of the functioning of a real or proposed system by means of the functioning of another. The key power of modelling is the ability to model the behaviour of the real system as time progresses, and study the results to gain insights into its behaviour.

Computer modelling involves the need for some sort of software to represent the proposed system. The Mid-Level-Model (MLM) is a software model of the National Airspace System (NAS), developed by The MITRE Corporation's Center for Advanced Aviation System Development (CAASD), to study system-wide effects to the NAS for specific scenarios. MLM software is data driven; the model is specified based on user-defined and default data items.

B.2 Discrete Event Simulation

MLM is built around the principles of discrete event simulation. Discrete event simulation requires the presence of two key factors:

- Model Software
- Mechanisms for time advance

B.2.1 Model Software

Model Software: Model software is made up of entities. Entities are tangible elements found in the real world with respect to the system being modelled. Each identified entity exhibits a very specific functional behaviour of the system that is being modelled and plays a very specific role within the system. The aggregation of the functional behaviour of the individual entities represents the functional capability of the system as a whole.

There are two types of entities. They are:

- **Input Entity:** These are inputs to the modelled system and in the modelling world better referred to as "temporary entities". Input entities get very often confused with user customizable system configurable parameters (discussed below). The easiest way to recognize the input entity(ies) to a system is to identify the entity(ies) whose absence from the system will produce no insights to the working of the system. Input entities are temporary as they exist only for short durations and are only created on an as need basis and at very specific times. They cause fluctuations in the system output, especially when the system or components within the system are subject to different boundary conditions. These entities could also exhibit different types of functionality in which case the fluctuations to the system can be studied for different kinds of input.
- **Permanent Entity:** Permanent entities exhibit specific functional behaviour within the system being modelled. They typically exist through the entire simulation run time and are created when the system comes up and are destroyed only when the system itself shuts down or at the exhaustion of the inputs. They have the unique quality of being able to facilitate or inhibit the flow of a temporary entity as the temporary entity traverses the system. To study the

behaviour of a system, either permanent entities are calibrated for varying boundary conditions while maintaining constant input or permanent entities are maintained at constant values while changing the input characteristics.

System Configurable Parameters: These are parameters that are user configurable and are used to alter the default functionality or threshold of the individual entities or the system as a whole. If the software provides it, users use this capability to configure the system for different scenarios to study the similarities or fluctuations in the system output, due to the effect of the interaction between input entities and permanent entities.

In the NAS the input entities are flights, and the permanent entities are airports, sectors, air traffic Controllers (ATCs), and communications, navigation, and surveillance (CNS) systems. The flights, airports, sectors, ATCs, and CNS systems comprise the NAS system. The flight entities enter the NAS and requests the services from the permanent entities to complete the flight. Routing, weather, and traffic flow management (TFM) are functional components that affect the performance of the system as a whole by imposing specific kinds of boundary conditions on the system entities.

MLM, which models the NAS, has one input entity, the Flight entity. Flight entities have the capability to change its functional behaviour based on the type of the aircraft for the specific flight. The number of flights into MLM can also be varied. MLM implements Airport and Sector as permanent entities. Their services are requested by the flight object to complete a simulated flight. MLM provides system configuration parameters to customize routing, weather, and TFM functionality that can be used by the analyst to modify the boundary conditions of the flights, airports and sector entities for specific studies.

B.2.2 Mechanisms for Time Advance

The “mechanism for time advance” is provided by the SLX environment. Time is advanced based on the next event and not based on time slicing. With the next event, the model is advanced to the time of the next significant event. Hence if nothing is going to happen in the next few minutes, SLX will move the model forward by few minutes in one go and run the first event that is scheduled for that time. Advancing time in this fashion is efficient and allows for speedy evaluations. SLX is also the modelling tool which provides a language definition and compiler capability to develop the model.

B.3 MLM High Level Software Architecture

The Mid-Level-Model software architecture is an actor-based model. An actor is an entity (input or permanent) that models a very specific functional behaviour of the system. In actor-based model architecture, each actor is driven by user-supplied scripts/data that controls the behaviour of the actor. In the absence of a script or user data, the actor follows a default approach. There are three types of actors:

- **Requesting Actors:** These actors asks for clearance from the authority actor to execute the next executable source code step.
- **Authority Actors:** These actors typically hold resources that need to be acquired by the requesting actor. If the resource is unavailable the requesting actor is made to wait till the resource is available. Authority actors from time to

time may switch roles and become requesting actors especially if they need to obtain the resources from other actors.

- **Passive Actors:** These actors do not hold any resources that a requesting actor or authority actor uses and is not called upon by any of the other actors to complete a instance. These actors are called by the system on a periodic basis. They are used merely for monitoring purposes and for modifying configurations when thresholds are met and for user input detection.

The predominant MLM actors are:

- **Flight Actor:** This actor is designed as a **requesting actor** and is the input entity into the system. There exists one flight actor for every flight entering the system. Sub-functionality provided by the flight actor is pushback-times and taxi-out-time.
- **Airport Actor:** This actor is designed as an **authority actor** and holds several key resources before a flight can traverse the system. The resources being modelled by Airport are:
  - Push Back
  - Taxi Out
  - Departure Queue (Runaway)
  - Arrival Queue (Runaway)
  - Taxi In
  - Gate Clearance
- **Sector Actor:** This actor is designed as an **authority actor**. This actor provides clearance delivery as a flight traverses from one sector to another. There is one such actor for every defined sector in the NAS. This actor also models the following:
  - <Airport>_dep (queue modelling the departure terminal airspace for every modelled airport)
  - <Airport>_arr (queue modelling the arrival terminal airspace for every modelled airport)
- **Statistics Actor:** The statistics actor is a **passive actor** and its role is to collect metrics of interest as the simulation unfolds.
- **Animation Actor:** The animation actor is a **passive actor** and its role is to generate output for the Proof software (an external animation package) on a periodic basis with data from the model.

Figure B.3-1 is an illustration of the relationship between the various actors within the MLM system as well as the functionality. As mentioned earlier, each actor can be controlled through various user supplied parameters. The box identified as "MLM System Configuration Parameters" is **not an actor**, but is merely a file which is read in by MLM and sets the input and output specifications.

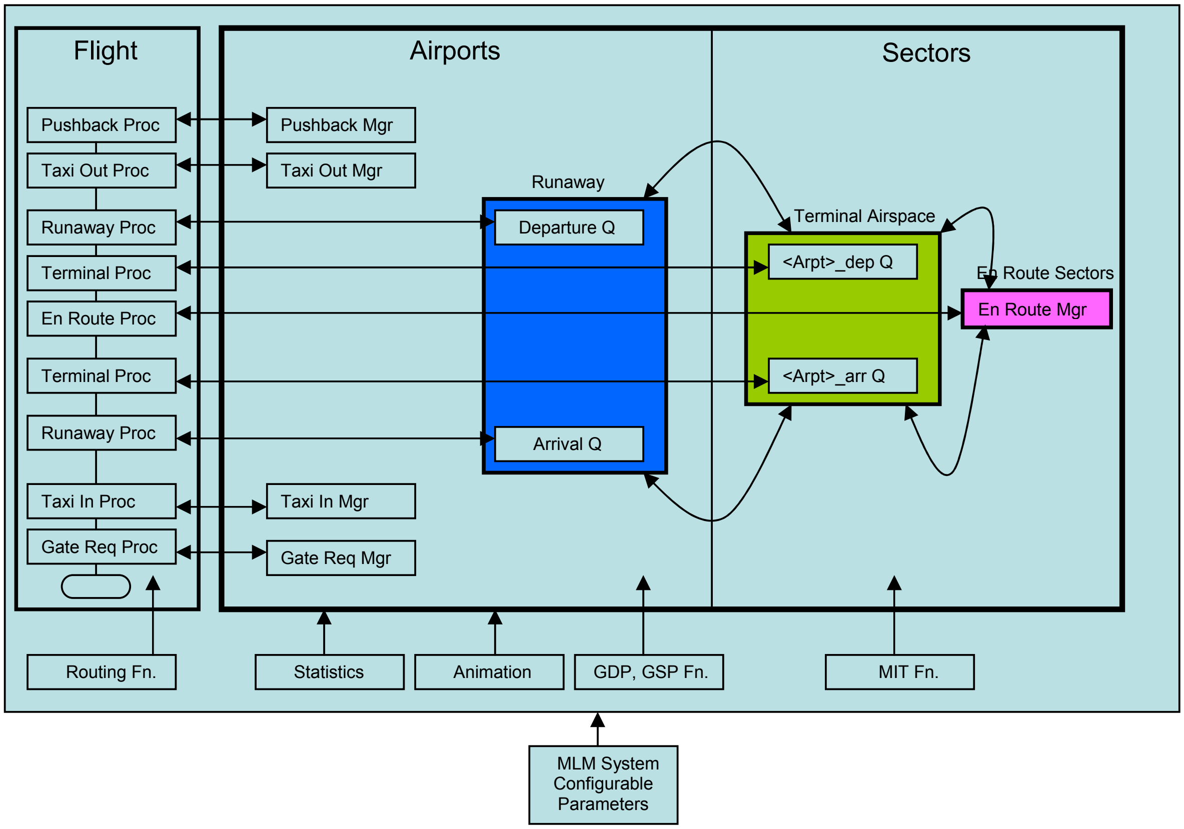

Figure B.3-1: MLM High Level Software Architecture

B.4 MLM Applied to the COCR

The role of MLM in development of the COCR is two-fold:

- Provide a crosscheck of Peak Instantaneous Aircraft Counts (PIACs) as derived by the EUROCONTROL SAAM Model.
- Provide PIACs for the U.S. NAS for specific milestones in the 2004-2030 timeframe.

The process followed mirrors that of the SAAM tool, however, the goal was primarily to obtain PIACs only for En Route, as Oceanic, Terminal and Surface results will require MLM adaptation beyond the scope of expected work on COCR v1.0.

We asked the MLM modellers to perform runs of existing scenarios for 2004, 2013, 2020 and then to use regression analysis for 2030 PIACs. What was achieved was a distribution of En Route PIACs for all NAS sectors, from which a maximum sector PIAC could be identified. While doing so, it became apparent that, in the longer term, the primary European concept to dealing with increased demand was to spread the additional traffic out across the day. In the United States, the concept is to move the additional traffic to satellite airports. This is consistent with the Joint Planning and Development Office's vision for the NextGen.

U. S. concepts also include the addition of thousands of Micro jets and Unmanned Aerial Systems.

NAS sectors are based upon strict geographic control principles. It is expected that PIACs obtained through this process would become the basis for determining capacity of future, larger sized sectors.

MLM Results were consistent with SAAM results in the En Route service domain through 2020, but differ significantly after 2020. It was therefore felt that the COCR should reflect both sets of results.

Appendix C QUEUING MODEL DESCRIPTION

C.1 INTRODUCTION

This appendix describes the priority queuing analysis used to calculate the required channel capacities for the Future Radio System (FRS) based on the allocated FRS delay requirements defined in the Future Communications Study (FCS) Communications Operating Concepts and Requirements (COCR) document.

The priority queuing analysis is a technique for estimating channel capacity to meet the FRS delay requirements for a given message and aircraft traffic loads. Priority queuing analysis may not take into account the details of the network protocols and the technical implementations of the FRS. The accuracy of the results depends on the assumptions built into the model and the inputs to the model.

This appendix is organized as follows:

- Section C.1 Introduction
- Section C.2 Data Channel Capacity Requirement Analysis Process and Inputs: This section describes data channel capacity requirement analysis process, inputs, and some assumptions made in the analysis.
- Section C.3 Data Channel Capacity Priority Queuing Analysis: This section describes the priority queuing models and the analysis process.
- Section C.4 Priority Queuing Analysis Basics: This section presents the basics of priority queuing analysis.

C.2 DATA CHANNEL CAPACITY REQUIREMENT ANALYSIS PROCESS AND INPUTS

Figure C-1 gives an overview of the service volume data channel capacity requirement analysis process. It consists of inputs that define the problem, a process for solving the problem, and the desired output.

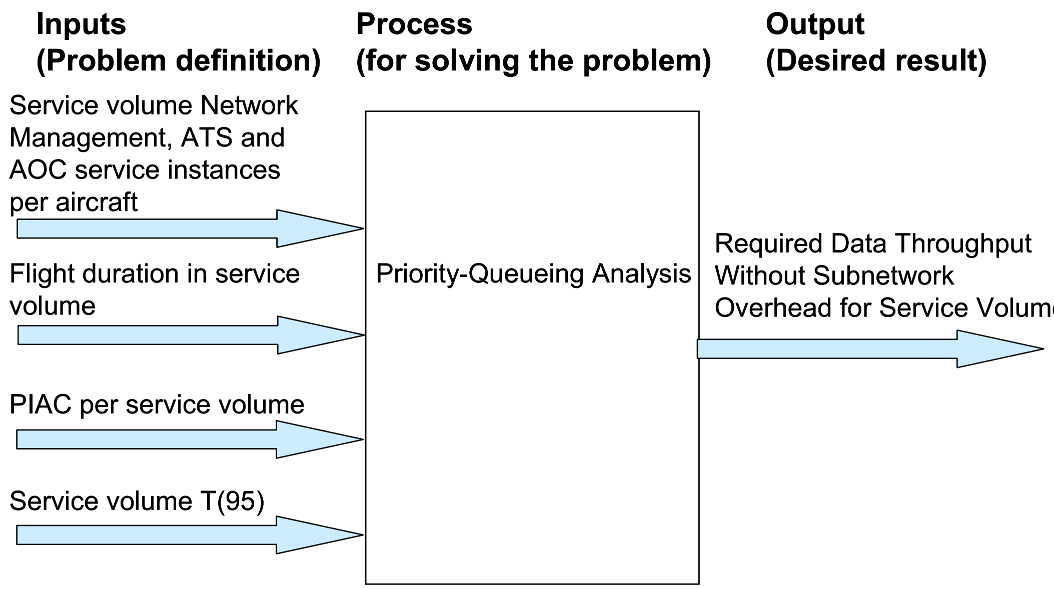

Figure C-1: An Overview of Service Volume Data Channel Requirement Analysis Process

As seen in Figure C-1, there are 4 inputs that define the problem:

1. The service volume Air Traffic Service (ATS) and Aeronautical Operational Communications (AOC) message traffic between each pair of aircraft and ground systems
2. Average flight duration in service volume
3. Peak Instantaneous Aircraft Count (PIAC) in each service volume
4. The Required Communications Technical Performance (RCTP) for the messages, i.e., 95^{th} percentile FRS end-to-end delay TT(95)

C.2.1 ATS and AOC Traffic

The ATS and AOC traffic describe the statistics for each application service in a service volume including uplink and downlink message sizes and service instances.

C.2.2 Flight Duration in Each Position/Sector

Flight durations apply to both low and high-density positions/sectors and to arrival and departure phases of flight. Flights durations are used with service instances to derive the message arrival rates that are used in the requirement analysis.

C.2.3 PIACs

PIACs in each high and low-density service volume (position/sector) in each domain have been used in accordance with the selected values in the main document. PIACs are used with the per aircraft message traffic defined in the data loading tables to derive the total message traffic in a service volume.

C.2.4 Data Communications Equipage

The PIAC represents the maximum number of aircraft in a position/sector. Of this number, a percentage of aircraft is equipped for data communications service. This percentage multiplied by the PIAC would represent the maximum number of aircraft that use the data communications service in a position/sector.

C.2.5 Percentage Departure

In the airport and TMA domains, a distinction is made between departing and arriving aircraft because they may use different data communications services and have different service instances. In the analysis process, it is assumed that a certain percentage of data communications equipped aircraft are departure aircraft and the remainder arriving aircraft. The mix of departing and arriving aircraft produces the aggregate data traffic for a position/sector.

C.3 DATA CHANNEL CAPACITY PRIORITY QUEUING ANALYSIS

C.3.1 Definitions

The following are the definitions and descriptions of most of the symbols used in this section.

Symbol	Definition/Description
ATS	Air Traffic Service
AOC	Aeronautical Operational Control
λ_{AGi}	Message arrival rate Air-to-Ground for priority i
λ_{GAi}	Message arrival rate Ground-to-Air for priority i
λ_{GAAGi}	Message arrival rate Ground-to-Air and Air-to-Ground for priority i
ULD Msg	Departure-aircraft UpLink Message size for a given priority
ULD λ	Departure-aircraft UpLink message arrival rate per aircraft for a given priority
ULD λ_T	Departure-aircraft UpLink message arrival rate for a service volume (position/sector) for a given priority
DLD Msg	Departure-aircraft DownLink Message size for a given priority
DLD λ	Departure-aircraft DownLink message arrival rate per aircraft for a given priority
DLD λ_T	Departure-aircraft DownLink message arrival rate for a service volume (position/sector) for a given priority
ULA Msg	Arrival-aircraft UpLink Message size for a given priority
ULA λ	Arrival-aircraft UpLink message arrival rate per aircraft for a given priority
ULA λ_T	Arrival-aircraft UpLink message arrival rate for a service volume (position/sector) for a given priority
DLA Msg	Arrival-aircraft DownLink Message size for a given priority
DLA λ	Arrival-aircraft DownLink message arrival rate per aircraft for a given priority
DLA λ_T	Arrival-aircraft DownLink message arrival rate for a service volume (position/sector) for a given priority
S_iMsg	Service i Message size for a given priority
S_iI	Service i Instance for a given priority
Msg	Aggregate message size for a given priority
I	Aggregate instance for a given priority
λ	Message arrival rate for a given priority
UL Msg	UpLink Message size for mixed departure and arrival for a given priority
UL λ_T	UpLink message arrival rate for mixed departure and arrival for a service volume (position/sector) for a given priority
DL Msg	DownLink Message size for mixed departure and arrival for a given priority
DL λ_T	DownLink message arrival rate for mixed departure and arrival for a service volume (position/sector) for a given priority
Msg_T	Aggregate uplink and downlink Message size for mixed departure and arrival for a given priority
λ_T	Aggregate uplink and downlink message arrival rate for mixed departure and arrival for a service volume (position/sector) for a given priority

C.3.2 Priority Queuing Analysis Models

This section presents the queuing analysis models used to obtain the results.

C.3.2.1 ATS and AOC Traffic on the Same Channel

In this set of models, ATS and AOC traffic share 1 single queue. 2 separate models were developed ─ separate channels for uplink and downlink traffic and shared channel for uplink and downlink traffic. Figure C-2 shows the first model that uses 2 separate channels for ATS and AOC traffic ─ 1 uplink and 1 downlink.

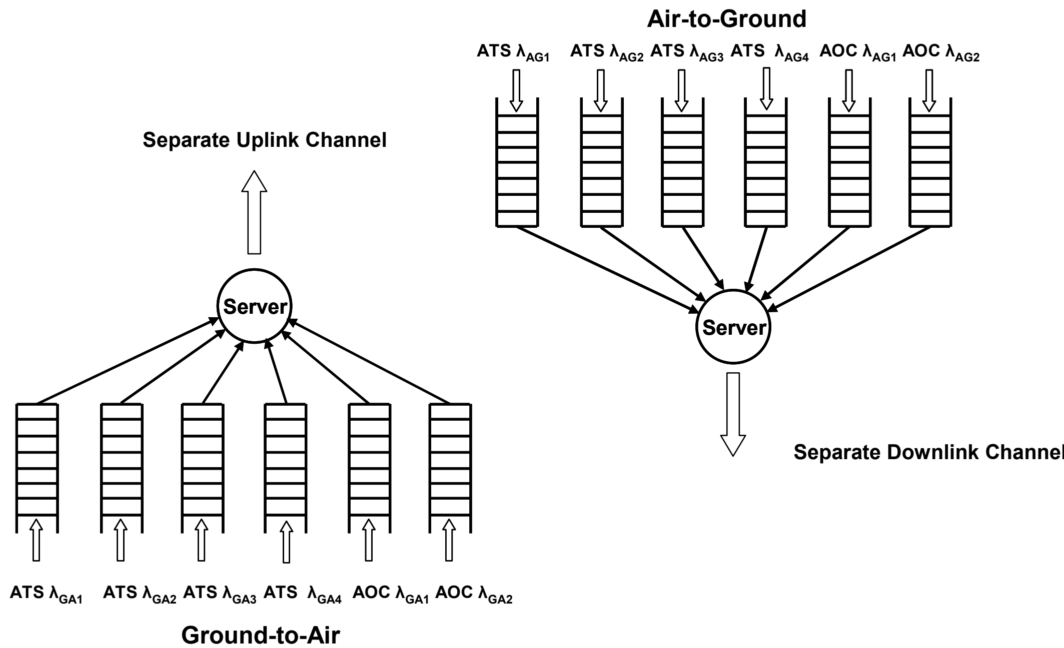

Figure C-2: Combined ATS and AOC Traffic Separate Uplink and Downlink Channels

Figure C-3 shows the second model that uses 1 channel for uplink and downlink ATS and AOC traffic.

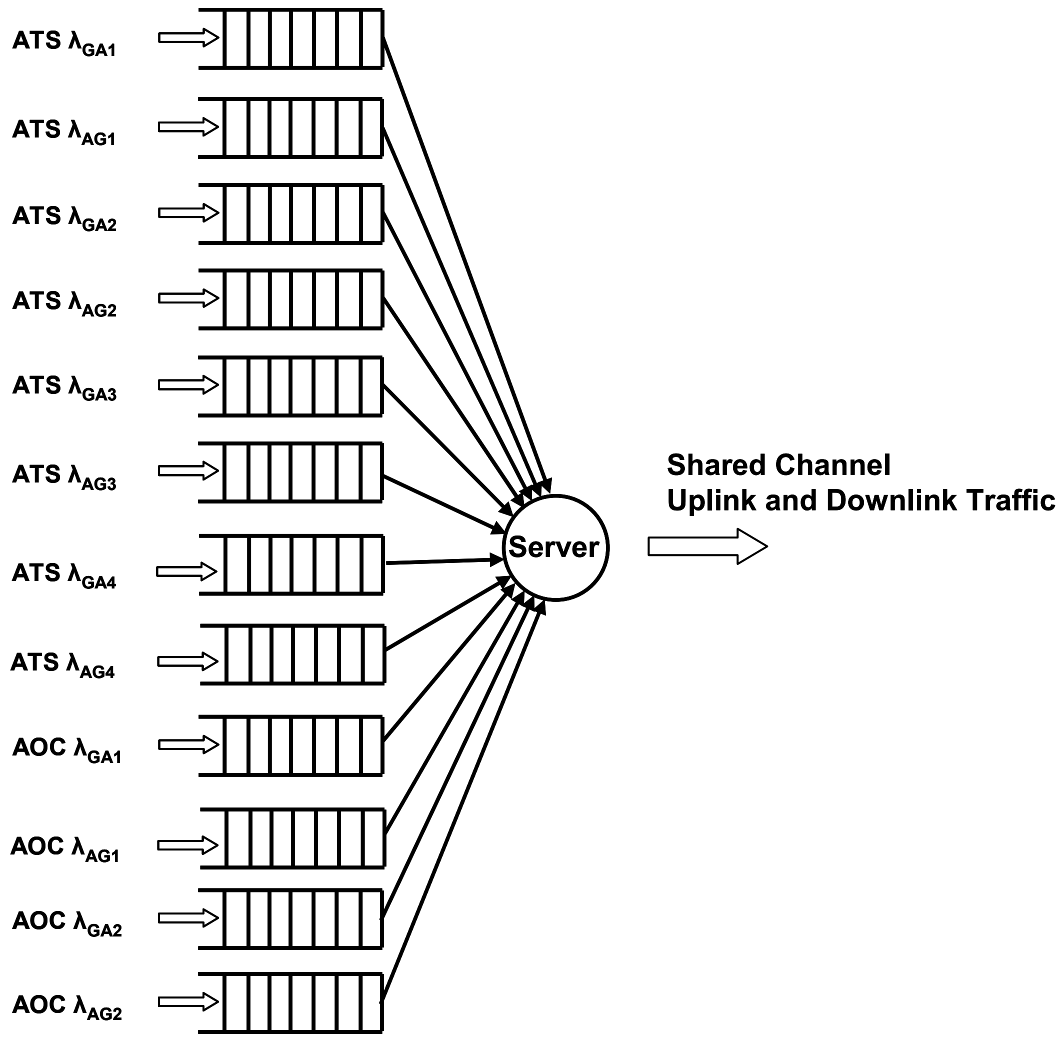

Figure C-3: Shared Channel for ATS and AOC Uplink and Downlink Traffic

C.3.2.2 Separate ATS and AOC Channels

In this set of models, ATS and AOC traffic use separate channels. 2 separate models were developed – separate channels for uplink and downlink traffic and combined channels for uplink and downlink traffic. Figure C-4 shows the first model that uses 4 separate channels for ATS and AOC traffic – 1 ATS uplink, 1 AOC uplink, 1 ATS downlink, and 1 AOC downlink.

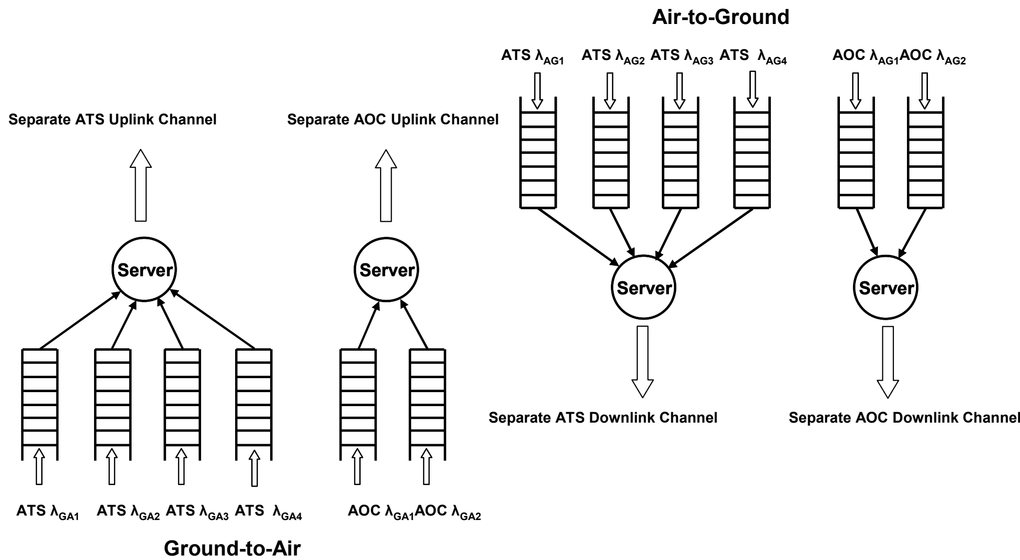

Figure C-4: Separate ATS and AOC and Separate Uplink and Downlink Channels

Figure C-5 shows the second model that uses 1 channel for uplink and downlink ATS traffic and 1 channel for uplink and downlink AOC traffic.

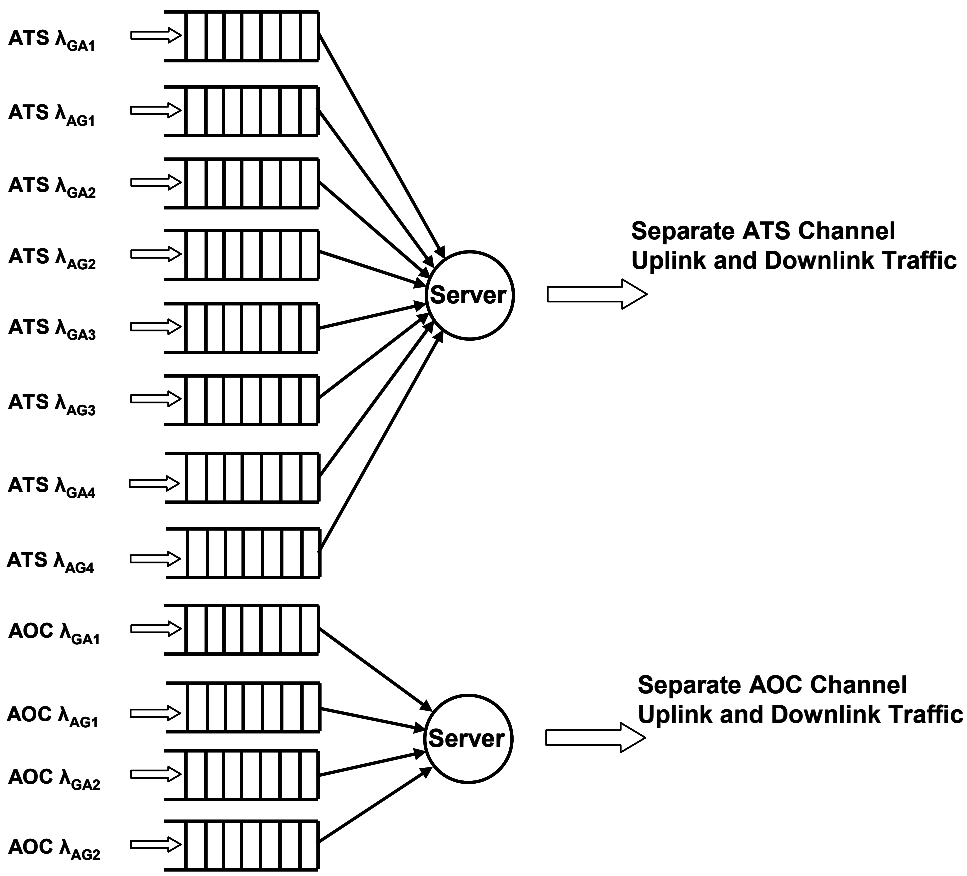

Figure C-5: Separate ATS and AOC Channels with Combined Uplink and Downlink Traffic

C.3.3 Traffic Model Development

Figure C-6 shows the 2-phase priority queuing analysis process for a mixed aircraft arrival and departure environment in a service volume. The first phase is the traffic model development phase, and the second phase is the priority queuing analysis phase. The first phase which is discussed in more detail later includes developing traffic statistics for departure and arrival aircraft based on data loading tables. The queuing analysis which is also discussed in more detail later consists of analysis for separate uplink and downlink channels and shared uplink and downlink channel.

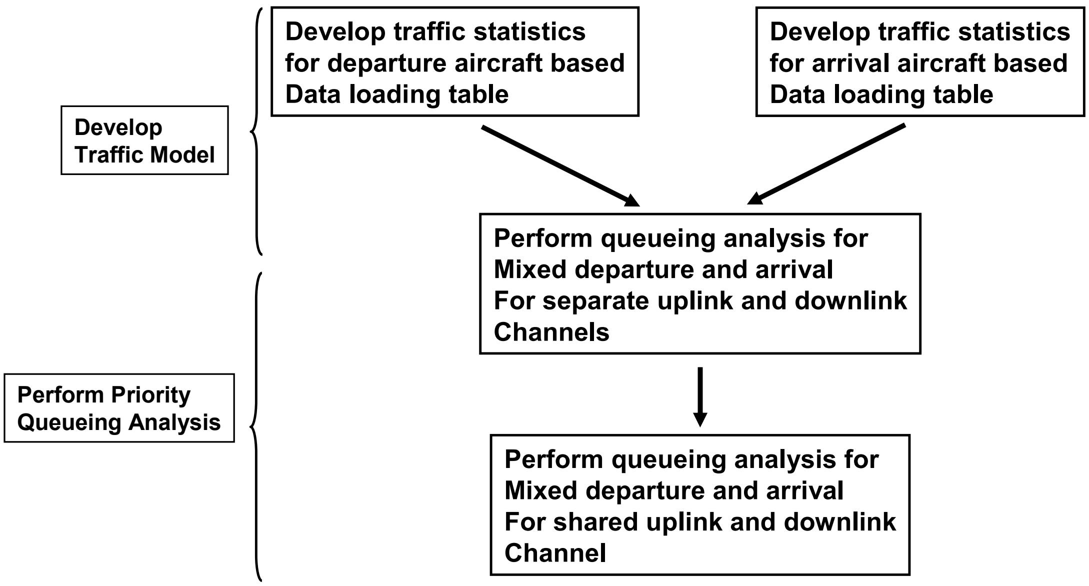

Figure C-6: Priority Queuing Analysis Process for a Mixed Arrival and Departure Service Volume

C.3.3.1 Departure Aircraft

Figure C-7 shows a 2 part traffic model development process for departure aircraft ─ per aircraft and per service volume.

Per Aircraft
Sort services into similar priorities
For each Priority
Develop departure uplink message statistics
? Uplink average message size, ULD Msg
? Uplink message arrival rate, ULD ?
Develop departure downlink message statistics
? Downlink average message size, DLD Msg
? Downlink average arrival rate, DLD ?

⇩

Per Service Volume
For each Priority
Develop departure uplink message statistics
? Uplink average message size, ULD Msg
? Uplink message arrival rate, ULD $?_T$ = PIAC * Equipage * Percent Departure * ULD ?
Develop departure downlink message statistics
? Downlink average message size, DLD Msg
? Downlink average arrival rate, DLD $?_T$ = PIAC * Equipage * Percent Departure * DLD ?

Figure C-7: Departure Aircraft Traffic Statistics Development Process

The per aircraft process consists of developing departure and arrival aircraft message traffic based on departure and arrival message traffic in ATS and AOC data loading tables. The services in the data loading tables are sorted by priority. For each priority, departure uplink and downlink traffic statistics are developed. The departure uplink statistics consists of the following:

- Uplink average message size, ULD Msg
- Uplink message arrival rate, ULD λ

The departure downlink statistics consists of the following:

- Downlink average message size, DLD Msg
- Downlink message arrival rate, DLD λ

The per service volume traffic model is based on the per aircraft departure and arrival traffic, PIAC, equipage, and the departure and arrival mix. For each priority, departure uplink and downlink traffic statistics are developed. The departure uplink statistics consists of the following:

- Uplink average message size, ULD Msg
- Uplink message arrival rate, ULD λT = PIAC * Equipage * Percent Departure * ULD λ

The departure downlink statistics consists of the following:

- Downlink average message size, DLD Msg

- Downlink message arrival rate, DLD λT = PIAC * Equipage * Percent Departure * DLD λ

Aggregate Message Size and Arrival Rate

Figure C-8 shows the methods for calculating the aggregate message size, instance, and message arrival rate for each priority. The service message size and instance are represented by S_iMsg and S_iI respectively.

Calculate aggregate message size from service message sizes

$$Msg = \sum_{i=1}^{N} (S_i Msg * S_i I) / \sum_{i=1}^{N} S_i I$$

Calculate aggregate instance from service instances

$$I = \sum_{i=1}^{N} S_i I$$

Calculate average message arrival rate

λ = I/Flight Duration

Figure C-8: Methods for Calculating Aggregate Message Size, Instance, and Arrival Rate for Each Priority

C.3.3.2 Arrival Aircraft

Figure C-9 shows a 2 part traffic model development process for arrival aircraft — per aircraft and per service volume.

Per Aircraft
Sort services into similar priorities
For each Priority
Develop arrival uplink message statistics
? Uplink average message size, ULA Msg
? Uplink message arrival rate, ULA ?
Develop arrival downlink message statistics
? Downlink average message size, DLA Msg
? Downlink average arrival rate, DLA ?

⇩

Per Service Volume
For each Priority
Develop arrival uplink message statistics
? Uplink average message size, ULA Msg
? Uplink message arrival rate, ULA $?_T$ = PIAC * Equipage * (100 - Percent Departure) * ULA ?
Develop arrival downlink message statistics
? Downlink average message size, DLD Msg
? Downlink average arrival rate, DLA $?_T$ = PIAC * Equipage * (100 - Percent Departure) * DLA ?

Figure C-9: Arrival Aircraft Traffic Statistics Development Process

C.3.4 Queuing Analysis Process

C.3.4.1 Mixed Departure and Arrival for Separate Uplink and Downlink Channels

Figure C-10 shows the queuing analysis process for mixed departure and arrival service volume for separate uplink and downlink channels. The process consists of developing separate uplink and downlink traffic statistics and performing queuing analysis to calculate the required uplink and downlink channel capacities.

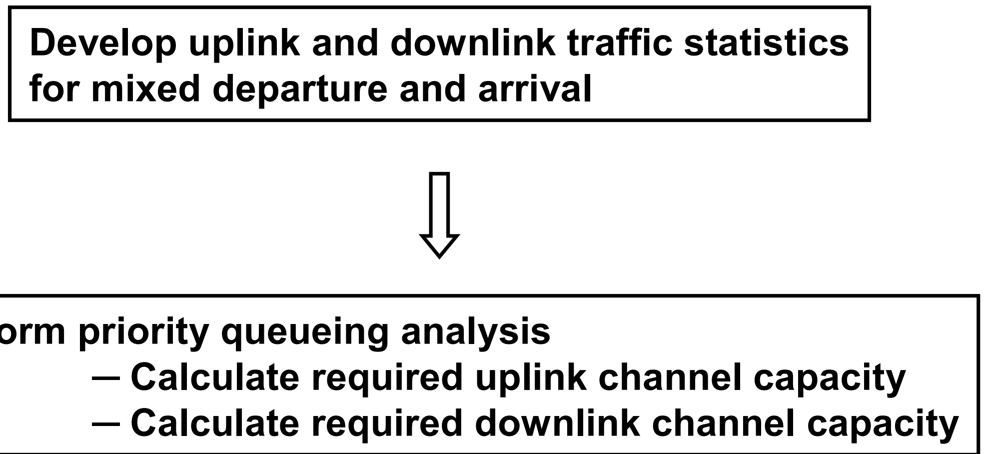

Figure C-10: Queuing Analysis Process for Mixed Departure and Arrival for Separate Uplink and Downlink Channels

<u>Traffic Statistics for Mixed Departure and Arrival Service Volume</u>

Figure C-11 shows the procedure for calculating the uplink and downlink traffic statistics for mixed departure and arrival service volume.

Develop Uplink Statistics

- **Uplink message size**

  $\text{UL Msg} = (\text{ULD Msg} * \text{ULD } \lambda_T + \text{ULA Msg} * \text{ULA } \lambda_T)/(\text{ULD } \lambda_T + \text{ULA } \lambda_T)$

- **Uplink message arrival rate**

  $\text{UL } \lambda_T = \text{ULD } \lambda_T + \text{ULA } \lambda_T$

Develop Downlink Statistics

- **Downlink message size**

  $\text{DL Msg} = (\text{DLD Msg} * \text{DLD } \lambda_T + \text{DLA Msg} * \text{DLA } \lambda_T)/(\text{DLD } \lambda_T + \text{DLA } \lambda_T)$

- **Downlink message arrival rate**

  $\text{DL } \lambda_T = \text{DLD } \lambda_T + \text{DLA } \lambda_T$

Figure C-11: Procedure for Calculating the Uplink and Downlink Traffic Statistics for a Mixed Departure and Arrival Service Volume

C.3.4.2 Mixed Departure and Arrival for Shared Uplink and Downlink Channel

Figure C-12 shows the procedure for calculating the shared uplink and downlink channel capacity for mixed departure and arrival service volume. The process consists of using the previously developed uplink and downlink statistics in the analysis.

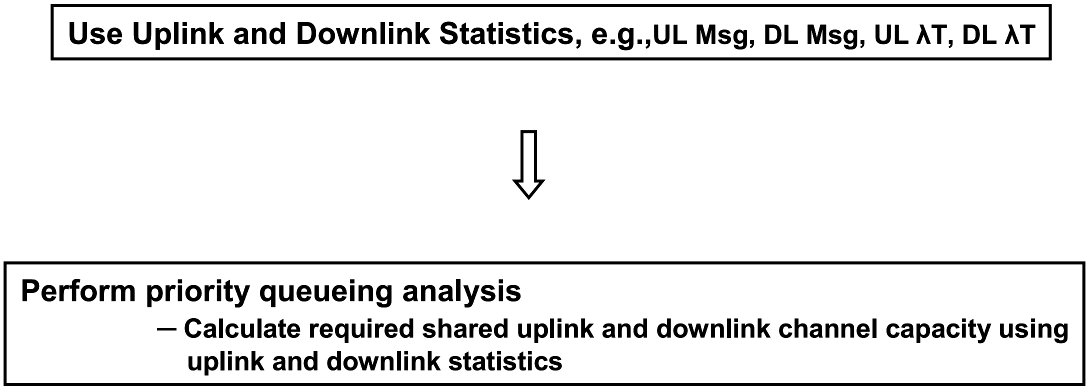

Figure C-12: Procedure for Calculating Channel Capacity for Uplink and Downlink Traffic Sharing the Same Channel

C.3.5 Priority Queuing Analysis Procedure

Figure C-13 shows a priority queuing analysis procedure. It requires a traffic model and the required 95th percent end-to-end delay as inputs.

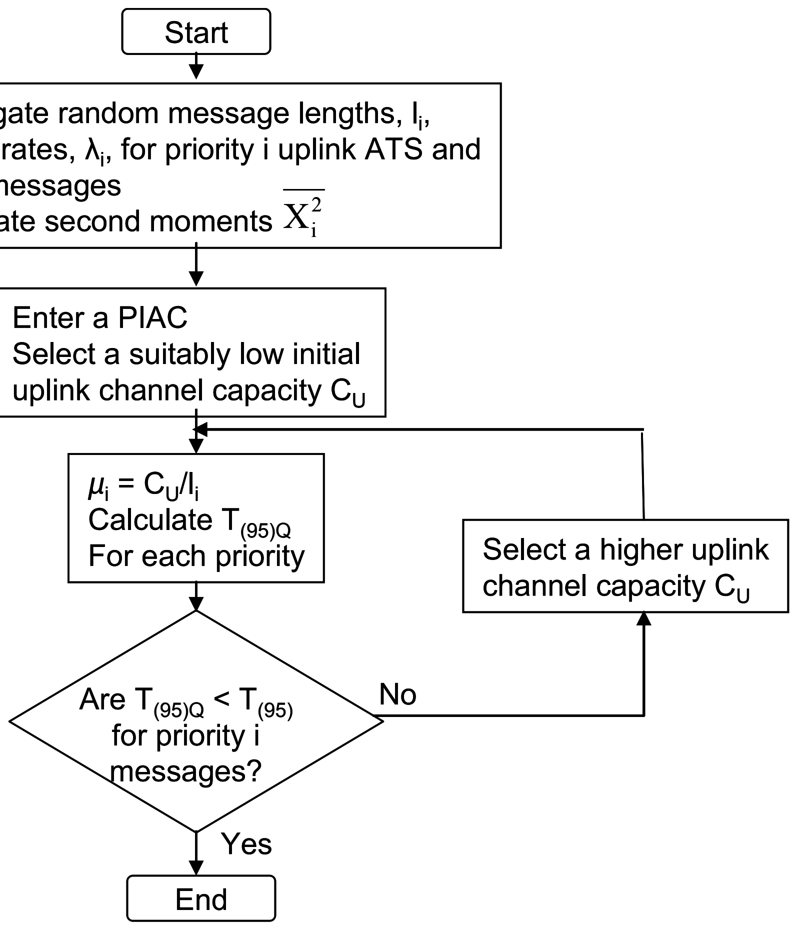

Figure C-13: A Priority Queuing Analysis Procedure

C.4 PRIORITY QUEUING ANALYSIS BASICS

Figure C-14 shows a priority queuing system with different classes of arrivals that have their own separate queues waiting for service by a single server. The different classes, A through K, have different arrival rates, λ_A through λ_K, and priorities, A being the highest and K the lowest. The messages in the higher priority queues are serviced ahead of those in the lower priority queues. The messages in each class are serviced at rates μ_A through μ_K. We assume a non-pre-emptive priority scheme where a message in service is allowed to complete its service even if a higher priority message is waiting.

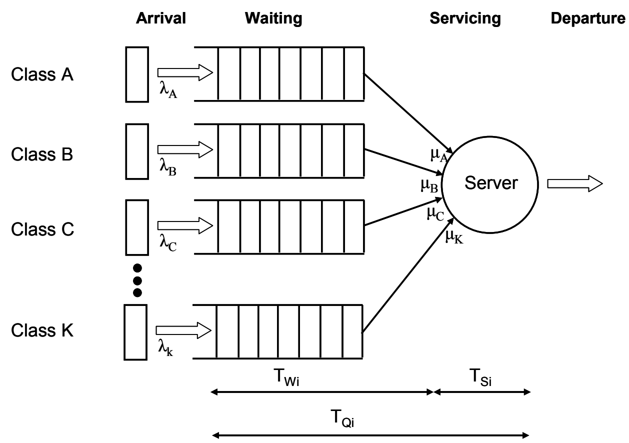

Figure C-14: Delay Analysis by Priority Queuing Method

The following are the definitions used in this paper and depicted in Figure C.4:

- Average class i message waiting time – T_{W_i}
- Average class i message service time – T_{S_i}
- Average class i message queuing delay – $T_{Q_i} = T_{W_i} + T_{S_i}$
- Class i utilisation – $\rho_i = \lambda_i / \mu_i$
- λi is the message arrival rate for class i messages
- μi is the message service rate for class i messages

Assuming a single-server M/G/1 queuing system, i.e., the arrivals are memory-less (Poisson) and service times have general distributions, the average waiting time, T_{W_i}, for the class i messages is [14]

$$T_{W_i} = \frac{\sum_{i=1}^{n} \lambda_i \overline{X_i^2}}{2(1-\rho_1-\ldots-\rho_{i-1})(1-\rho_1-\ldots-\rho_i)} \quad (1)$$

Where:

[14] D. Bertsekas and R. Gallager, *Data Networks*, Prentice-Hall, 1987.

$\overline{X_i^2}$ is the second moment of the service time T_{S_i}

The following are the equations for calculating the second moments for the exponential and constant distributions.

Exponential: $\overline{X^2} = \frac{2}{\mu^2}$ (7) Constant: $\overline{X^2} = \frac{1}{\mu^2}$ (8)

Note: For COCR Version 2.0, the second moment of the service time is assumed to be the variance in the COCR service message sizes plus the average message size squared divided by the selected capacity value. Version 1.0 queuing results assumed an exponential distribution.

The average queuing time, T_{Q_i}, for the ith priority message is

$$T_{Q_i} = \frac{1}{\mu_i} + T_{W_i} \quad (2)$$

Note: *The term, $1/\mu_i$ represents the message send time. COCR Version 1.0 results used the average send time for average message in the queue. COCR Version 2.0 uses the send time associated with the worst case COCR service assigned to the queue. This is the COCR service with the largest message size. Individual COCR service latencies are not insured unless the worst case COCR service size is used for the message send time.*

From (1), the average waiting time for the highest priority message, T_{W_A}, is

$$T_{W_A} = \frac{\sum_{i=1}^{n} \lambda_i \overline{X_i^2}}{2(1-\rho_A)} \quad (3)$$

The average queuing time for the highest priority message, T_{Q_A} is

$$T_{Q_A} = \frac{1}{\mu_A} + T_{W_A} \quad (4)$$

The rth percentile of the queuing time, $T(r)_Q$, can be derived from the average queuing time T_Q as follows:

$$T(r)_Q = \ln\left(\frac{100}{100-r}\right) T_Q \quad (5)$$

For example, the 95th percentile of the queuing time, $T(95)_Q$ is

$$T(95)_Q = \ln\left(\frac{100}{100-95}\right) T_Q \quad (6)$$

Appendix D DEFINITIONS

Air Traffic Control Sector	An airspace area of defined horizontal and vertical dimensions for which a Controller or group of Controllers (e.g., executive and planning Controller) has air traffic control responsibility.
Air traffic management	The aggregation of the airborne functions and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations. (ICAO PANS-ATM)
Air traffic management system.	A system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground and/or space-based communications, navigation and surveillance.
Availability (inherent)	Probability that the equipment comprising the system is operational and conforms to specifications, excluding planned outages and logistics delays.
Availability of use (A_U)	Availability of use is the probability that the communication system between the two parties is in service when it is needed (DO-264). The time a system is not available while repairs are underway (logistics delay, MTTR, etc.) reduces availability of use.
Availability of provision (A_P)	Availability of provision is the probability that communication with all aircraft in the area is in service (DO-264).
Call Establishment Delay	The total time taken between the PTT action by the User and the time for the squelch to operate in the receiver (of the party being called). (EUROCAE WG67-1)
Continuity	Probability that a transaction will be completed having meet specified performance (assuming the system was available when the transaction is initiated). The value for the continuity parameter is based on the acceptable probability of detected anomalous behaviours of the communication transaction. Detected anomalous behaviours include, but are not limited to (ICAO RCP Manual Draft v4): • Late transactions; • Lost messages or transactions that cannot be recovered within the expiration time • Duplicate messages or transactions that are forwarded and/or used; and • Uncorrected detected message errors.
Integrity (I_{UCT})	Integrity is the acceptable rate of transactions that are completed with an undetected error (DO-264). Undetected errors include, but are not limited to (ICAO RCP Manual Draft v4): • Undetected corruption of one or more messages within the transaction; • Undetected misdirection of one or more messages within the transaction; • Undetected delivery of message in an order that was not intended; • Undetected delivery of a message after the communication

	transaction time; and • Undetected loss of service or interruption in a communication transaction.
Primary Means of Communication	Primary Means: In today's environment, the normal means of communicating is via voice. Established standards acknowledge this distinction in that data communications remain as an alternate or supplemental means of communicating. Alternate means of communications are neither required, nor are they used as a means of certification by U.S. authorities. In the future, this relationship will be reversed as the performance of data communications required for normal operations will be improved to such an extent that it will be deemed the only means for some services.
OAT and GAT Traffic	In many parts of Europe where a division of labour is used, the military Controller is collocated with the Controllers in charge of civil traffic-they may be in the same room, sitting right next to each other. In other locations, the military Controller works out of a facility that is physically separate from where his civil counterparts work. In either case, the military and civil Controllers work behind the scenes with each other to de-conflict the two types of traffic. OAT and GAT This division of labour is the root of the OAT and GAT "systems" which are found in parts of Europe. Simply put, the GAT system is designed to accommodate civil IFR traffic or military IFR traffic that chooses to abide by the procedures established for civil IFR traffic. This GAT system is managed by a network of civil Controllers while the OAT system is designed to accommodate military traffic only and is managed by a network of military Controllers using discrete frequencies. It is important to emphasize that suitably equipped military aircraft are given the option of filing as either OAT or GAT, but civil aircraft are not allowed this same option as they are required to file as GAT.
PIAC	Peak instantaneous aircraft count, the highest number of aircraft in a selected volume during the selected window of time
Push to Talk (PTT)	The physical action taken by the 'User' in operating his/her transmitter key. The general term 'User' refers to a pilot or Controller. The term 'key' is used to denote any type of device including buttons, levers, foot switches, computer mouse and LCD/plasma panel segments, etc. (EUROCAE WG67-1)
PTT Delay	This is the delay arising from the need to operate a transmitter remotely and would be nil if the User was actually physically located in the same place as the transmitter. (EUROCAE WG67-1)
Receiver Activation Delay	The total time taken for a receiver to have recognised the presence of a radio signal of designed minimum quality causing the squelch to operate. (EUROCAE WG67-1)
Reliability	See Availability (inherent)
Service Instance	A set of one or more messages and/or transactions associated with

	completing a objective. For example, a Flight Crew request followed by a Controller clearance followed by a Flight Crew acknowledgement would constitute a single service instance that contains three messages and two transactions.
Technical delay, one way	Time required by the system to deliver a message, beginning with user action to send the message, and ending upon notification of recipient of message receipt. Typically accounts for half of a transaction.
Technical delay, two way	Time required by the system to deliver a message, beginning with user action to send the message, and ending upon notification by initiating user of reply receipt, excluding any user response time. Typically, that part of TT(95) allocated to system.
Transaction	A two-way operational communication process (e.g., Controller and pilot, pilot and pilot, or Controller and Controller. It contains the outgoing request message, the Controller or pilot response time and the incoming response message. Communications exchanges that have multiple responses, i.e., the STANDBY, followed by the operational response, are treated as two transactions. (DO-264)
Transaction Time (TT)	The transaction time is the time needed by a pilot and a Controller to exchange a pair of messages. This time represents the sum of the delivery time of incoming and outgoing messages and the Controller or pilot response time. (DO-264, Annex C.3.1.5.1)
Transmitter Activation Delay.	The total time taken between the PTT action by the User and the time that the transmitter has attained its designed operating power (EUROCAE WG67-1)
95% Transaction Time (TT95)	The time before which 95% of the transactions are completed. (DO-264)
TT(95)RCTP	95% of transactions are completed with a technical delay, two way with this time
TT(95)RCTP, one way	95% of transactions are completed with a technical delay, one way within this time
Voice Access Delay	The one-way user-to-user delay starting with the voice initiation event (e.g., PTT signal event) and ending with audio appearing at the remote end of the link, but excluding any human response times.
Voice Channel Setup Delay	Time needed for by the system to establish a path between users, prerequisite for voice access and communications.
Voice Latency	The one-way user-to-user voice delay between analogue system interfaces (HMIs) after the audio path has already been established.
User	A person who employs the services provided by the system. Typically a member of the aircraft cockpit crew, a member of the air traffic management team or flight operations personnel.

Appendix E FRS LATENCY ALLOCATION

The COCR FRS technical latency allocation is intended to include the SNDCF processing latency, the radio processing latency (both air and ground), the RF-based transmission latency (this is the latency associated with the channel RF-bit transmission rate), and any RF-based media access delays. It is important to note that the FRS boundary has been chosen to be the SNDCF interface (a logical, stack-based boundary) rather than a physical interface. The FRS technical latency is allocated from the overall system RCTP transaction time, TT95-RCTP.

E.1 Latency Allocation Methodology

The steps below describe the methodology for allocating the latency requirements to the FRS.

1. Start with the TT_{RCP} requirement.
2. Allocate the TT_{RCP} between the technical and human elements using an algebraic allocation, i.e., $TT_{95\text{-}RCP} = TT_{95\text{-}RCTP} + TT_{95\text{-}HUMAN}$.
3. Allocate the two-way $TT_{95\text{-}RCTP}$ into two one-way pieces, $TD_{95\text{-}RCTP}$ using the statistical allocation method described in Section 3.2 assuming that each one-way piece contributes equally to the two-way delay. Alternatively, an algebraic allocation could be made at this step.
4. Assuming estimated allocation percentages, statistically allocate the one-way delay among the ATSU, CSP, FRS, and External Airborne systems. Note: This step does not directly use the ground and airborne allocations of from prior work, since the FRS spans both the ground and airborne domains.
5. Evaluate the resultant statistically allocated figures for practically and reasonableness using a best effort attempt to equally distribute the difficulty in meeting the allocation. For example, it might be very difficult for FRS to met delays given the high likelihood of RF interference (a problem that the ATSU, CSP, and External Airborne equipment does not need to deal with). As another example, the processing requirements in the ATSU might be much greater (to authenticate security certificates) than the processing requirements in the FRS. The idea is to make a best effort at balancing the allocations such that a subsystem is not unfairly burdened.
6. As needed return to Step 3 above until a reasonable set of allocations is produced.

It is practical to develop the allocation percentages using the service with the most stringent TTRCP requirement. The reasonableness test can then be applied for worst cast conditions. The resulting allocations can be applied to services with larger (less stringent) TTRCP requirements with the assumption that the allocations will also be reasonable.

E.2 Statistical Allocation

A Poisson distribution is assumed for transaction times. Poisson distributions are commonly used to model message delays in queuing delay analyses. The allocation among system components is done using mean (average) delay values. The steps below describe the statistical allocation process:

1. Calculate the mean delay time using the 95% time and assuming a Poisson distribution.

   Note: A Poisson distribution calculator is available at:

   http://calculators.stat.ucla.edu/cdf/poisson/poissoncalc.php

2. Allocate the mean using the desired allocation percentages. If a component is allocated 10% of the mean, the component allocation is 0.1 times the system mean.

3. Calculate the 95% delay time for each of the components using the component mean delay value and assuming a Poisson distribution.

For example, assume a total 95% system delay of 10 seconds wherein the system consists of 3 components to be allocated 10%, 30% and 60% of the delay. First, you would obtain the mean system delay. Using the Poisson calculator (see link above), the system mean delay is 6.17 seconds. The mean delay allocations to the three components are 0.61, 1.85, and 4.31 seconds, respectively. Note: Values are truncated rather than rounded. Using the Poisson calculator and these mean values, the 95% delay values are 1.5, 3.8 and 7.4 seconds. Note: The sum of these three numbers are greater than 10 seconds, but the statistical allocation accounts for the fact that these three 95% delays do not happen at the same time. The system 95% delay is still 10 seconds.

E.3 Allocation Guidance

In reality, the allocation to the FRS should be based on what can reasonably be achieved. Annex E of DO-264 [43] provides guidance on allocation states:

> *Consideration should be given as to the reasonableness and practicability of the considerations and assumptions (be they procedural, functional, performance, environmental, etc.). In particular, is the human component being unduly relied upon? A reasonableness check could be to relate the intended system architecture with the existing architecture, for example data-link* replacing voice communication path to ensure that the safety objectives of the *new technology are not significantly different from the existing technology, given similar mitigation and similar hazard category.*

To that end, it is useful to review a number of prior assessments and associated assumptions, limitations, and notes. Some of these assessments were presented in Section 2.0 of this document and some of the information is newly introduced below.

- Recent VHF Digital Link (VDL)-2 simulation studies conducted to evaluate European capacity requirements have assumed a VDL-2 round trip delay of 8 seconds, i.e., TT_{VDL2} = 8 seconds [46]. This represents a 50% algebraic allocation to the VDL-2 subnet. Note that this study has assumed a limited set of COCR-defined operational services and looked primarily at an En Route deployment of VDL-2.
- A MITRE study [50] evaluated VDL-3 delays and estimated 95% uplink and downlink one-way delays of 0.8 and 5 seconds, respectively. This delay data assumes 18 aircraft and a defined Terminal Domain Message Traffic Model.

Note: The traffic load in this model was significantly higher than that used in [46].

- The system specification for the U.S. National Build 1.2 for Controller-Pilot Data Link Communication (CPDLC) requires an automation 95% delay time of 5 seconds (delay between Controller initiation and providing the message to the FAA Telecommunication Infrastructure, FTI, ground network).

These examples are technology specific; thus, should only be used to consider (not drive) FRS allocations.

E.4 FRS Latency Allocation

We start with step 3 in the proposed approach (see Section 3.1) given that the operational subject matter experts have already developed TD95 performance numbers for the end-to-end data communications. For Phase 1, the most stringent requirement is for ACL/ACM, so will start the allocation process with a TD95 = 8. Using the Poisson calculator, the mean one-way delay time (TDMEAN) is 4.695 seconds.

For the FRS, we will allocate this mean figure to the ATSU (e.g., automation), the CSP (e.g., network), the FRS, and the external aircraft (XAIR) equipment (e.g., FMS). The initial allocation percentage numbers for each component is 25%, 25%, 40% and 10%. These percentages are based on the following rationale:

- The FRS has the most restrictive transmission rate. Traditionally, the bit rates on the RF links are significantly less than that of the ground network. In addition, the RF link is subject to interference and is much more error prone than ground links, which will likely require the FRS system to retransmit many more messages than other components. Some reports have indicated that the present ACARS system looses on average 6% of the transmissions. Thus the FRS allocation is large in comparison to other components. The 40% allocation is similar to the 50% allocation assumed in [46]. A slightly smaller allocation is assigned, since the future end systems will likely require additional processing (security certificate processing). In addition, a smaller allocation adds a degree of conservatism.
- The DO-290 algebraic allocation to the airborne domain resulted in TD95-AIR of 2 seconds. From Boeing [49], the external equipment (other than VDR and CMU), the delay was estimated as 0.5 seconds. This represents about 6% of the system delay. Given that the FRS boundary is within the CMU, the assumed initial allocation will be a bit larger to account for CMU processing. Thus, the initial allocation of 10%.
- The remaining delay is allocated equally between the ATSU and the CSP, i.e., 25% each.

Using these component allocations and a system mean delay of 4.695 seconds, the mean delays for the ATSU, CSP, FRS and XAIR are 1.17375, 1.17375, 1.878, and 0.4695 seconds respectively. Using the Poisson calculator and truncating to the nearest tenth of a second, the associated 95% delays are 2.6, 2.6, 3.8, and 1.2 seconds respectively. These allocations seem reasonable.

While it might be desirable to increase the FRS allocation, it would need to be at the expense of the other allocations. The ATSU delay is already about 50% faster than previously specified performance requirements for data communications automation, i.e., 2.6 seconds versus 5.0 seconds.

Appendix F REFERENCE LIST

Ref #	Document Title	Author	Doc Ref	Date
1	ICAO Global ATM Operational Concept	ICAO	Doc 9750 AN/963	
2	Safety and Performance Requirements Standard for Air Traffic Data Link Services in Continental Airspace	RTCA/EUROCAE	RTCA DO-290/ EUROCAE ED-120	
3	Operational Requirements for Air/Ground Co-operative Air Traffic Services	EUROCONTROL	AGC ORD-01	
4	Roadmap for the Implementation of Data Link Services in European Air Traffic Management (ATM: Non ATS Applications)	European Commission		
5	Minimum Aviation System performance Standards for Automatic Dependent Surveillance – Broadcast	RTCA	DO-242A	
6	Next Generation Air Transportation System Integrated Plan (NGATS)	U.S. Department of Transportation		December 2004
7	National Airspace System Concept of Operations and Vision for the Future of Aviation	RTCA		
8	EUROCONTROL ATM Operating Concept Volume 1, Concept of Operations, Year 2011	EUROCONTROL		
9	ATM Implementation Roadmap – Short and Medium Term – Release Version 1.0	IATA		15 October 2004
10	EUROCONTROL Air/ground data volumes in Europe - version 0.B	EUROCONTROL		July 2000
11	Security Analysis Supporting the Communications Operating Concept and Requirements for the Future Radio System	EUROCONTROL/ FAA		September 2005.
12	EUROCONTROL/FAA Principles of Operation for the Use of Airborne Separation Assurance Systems Version: 7.1	EUROCONTROL/ FAA		19 June 2001
13	Guidelines for Approval of the Provision and Use of Air Traffic Services Supported by Data Communication	RTCA/EUROCAE	RTCA DO-264/ EUROCAE ED-78A	
14	FAA Safety Management System (SMS) Manual	FAA	ASD-100-SSE-1	
15	EUROCONTROL Safety Regulatory Requirement (ESARR 4) Set 1 Severity Indicators	EUROCONTROL		
16	COCR working paper AOC Transactions per Flight Domain	K De Vito	COCR-PSG-KD-09	

Ref #	Document Title	Author	Doc Ref	Date
17	“Dallas/Fort Worth International Airport Perimeter Taxiway Demonstration”	Buondonno, K. and Price, K	DOT/FAA/CT-TN03/19	July 2003
18	“Los Angeles International Airport Runway Incursion Studies, Phase I Baseline Simulation”	NASA Ames Research Center	FFC-LAX-R001	May 9, 2001
19	FCS Operational Concept and Requirements Group: A Voice Study Survey Characterizing Voice Channel Access by Airspace Domain	K De Vito		March 2005
20	Project EMERTA WP2-NGSS Study Synthesis Report	Project EMERTA		March 2001
21	PSG FRS Latency Allocation Proposal	Performance Sub Group (PSG)		
22	PSG Node Analysis - Nodes and Operational Service Connectivity	PSG		
23	PSG Large Airspace Volume Loading Proposal	PSG		
24	PSG Queuing and Loading Assumptions	PSG		
25	PSG ATN Stack Message Traffic Estimate (Network Layer)	PSG		
26	Voice Channel Impacts due to ASAS Application Usage	K De Vito		March 2005
27	Next Generation Satellite Communication System - Mission Requirements	P Platt		October 2003
28	One Sky Global ATM V1 2005+ - A strategy for Future ATM	IATA		
29	Time Required for Transmission of Time - Critical ATC Messages in an En Route Environment	Kim M Cardosi		
30	Communications Concepts - For FCOCR Meeting July 26th 2005	FAA		July 2005
31	Operational Concepts of Required Communication Performance	ICAO		
32	ATN Project ATN Implementation Task Force DRAFT ATN Scenario Definition	EUROCONTROL	DED6/ATN/ATNI-TF/DOC/25	July 1998
33	Modelling the Other Half of the Flow	S. Bradford, M. Rodgers, W. Colligan		
34	“Benefits of Controller-Pilot Data Link ATC Communications in Terminal Airspace”	Data Link Benefits Study Team,	DOT/FAA/CT-96/3,	September 1996
35	“Etude Vocalise”	L Gragila	CENA/ICS/R 02-002	July 2002
36	"MITRE-Sponsored Research: An Analysis of En Route Domain Air Traffic Control Voice Transcripts"	Hung, B		April 2005
37	AOC Message Volumes v0.2	PSG		

Ref #	Document Title	Author	Doc Ref	Date
38	PSG FIS Message Sizes v0.2	PSG		
39	FRS Loading Associated with Security	FAA		August 2005
40	ATS Message Sizes (UNICAST) v0.2	PSG		
41	Centre Sectors	Harry Eberlin		
42	NAS VHF Spectrum Survey Results			20 September 2005
43	Next Generation Air/Ground Communications System (NEXCOM) Safety and Performance Requirements (SPR)	RTCA	DO 284	
43a	Next Generation Air/Ground Communications System (NEXCOM) Safety and Performance Requirements (SPR) - Change 1	RTCA	DO 284 - Change 1	
44	ICAO Annex 10 - Vol 3	ICAO		
45	Terminal Radar Approach Control: Measures of Voice Communications System Performance	Prinzo & McClellan	DOT/FAA/AM-05/19	October 2005
46	EUROCONTROL VDLM2 Capacity Study	EUROCONTROL		
47	ICAO PANS-OPS	ICAO	Doc 4444	
48	ICAO Annex 11	ICAO		
49	Boeing Aircraft Delays	Boeing		
50	"A Simulation Study of the VDL Mode 3 Poll Scheduling Algorithm and Site Diversity", 22nd DASC, Indianapolis, IN	Brian T. Hung, MITRE/CAASD		14-16 October 2003
51	COTRAC Operational Safety Assessment Report	EUROCONTROL		8 March 2006
52	Baseline S&M OSA Worksheet		050726B	
53	Draft VoIP ATM System Operational and Technical Requirements	EUROCAE WG67		14 February 2007
54	Concept of Operations for the Next Generation Air Transportation System	Joint Planning and Development Office (JPDO)	DRAFT 5 Version 1.2	February 28, 2007
55	Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace (Oceanic SPR Standard)	RTCA/EUROCAE	DO-nnn (PU-24)	April 25, 2007
56	Safety, Performance & Interoperability Requirements Document for the ADS-B Non-Radar-Airspace (NRA) Application	RTCA	DO-303	December 13, 2006
57	Minimum Aviation System Performance Standards (MASPS) for Aircraft Surveillance Applications (ASA), Change 1	RTCA	DO-289 Change 1	December 13, 2006

Appendix G RELATIONSHIP OF THE RESULTS TO A REAL WORLD ENVIRONMENT

G.1 Introduction

The requirements of the FRS have been derived in the above sections independently from any specific technology or geographic location. Whilst this does not constrain the choice of technology, Appendix G provides realistic examples of how the generic requirements can be used in a practical way. The examples are not meant to be prescriptive, but just indicate how the results could be applied to estimate PIACs accounting for sector growth from Phase 1 to 2; to estimate PIACs for airspace volumes corresponding to the service volumes associated with particular technologies and to generally assess the application to modern, networked communications which might be devoid of geographic constraints. For example, one variation of this approach, not covered, could employ PIAC distributions derived from volumes associated with existing En Route sectors to allow assessment of large area volumes typically associated with satellite-based communications.

Two practical applications of the approach are documented in this chapter.

- Example One addresses application of the COCR in the ECAC
- Example Two addresses application to the U.S. NAS

Other approaches can be adopted drawing on the raw data which were used to feed the queuing model used in the loading calculations as discussed in Section 6.

G.2 Aircraft Density Calculation

In order to provide for consistency in results which could be applied anywhere in ICAO, a standard density measure was defined. Since it is expected that service volumes will still apply, even in the Phase 2 timeframe, the density was defined as:

Aircraft Density in Service Volume = Service Volume PIAC/Service Volume in nm^3

G.3 Example One (ECAC SV Density Calculations)

EUROCONTROL developed and operates a set of tools in order to assess quantitative information in support of development at Europe's airports, on air routes and the airspace system. One such tool is System for Traffic Assignment and Analysis at a Macroscopic Level (SAAM). SAAM is an integrated system for wide or local design evaluation, analysis, and presentation of Air Traffic Airspace/TMA scenarios. Details of the SAAM tool are given in Appendix A.

G.3.1 Modelling ECAC Airports, Terminal Areas and En Route Airspace

In reviewing the SAAM results a range of PIACs were noted for the service volumes used in the model. It was identified that the sectors were of different volume and therefore the number alone did not give an indication of traffic density. Consequently the number of aircraft per unit volume was derived to compare air traffic densities.

The volume of the SAAM service volumes was calculated using the lat-long co-ordinates and height based on spherical geometry mathematics.

G.3.2 ECAC Traffic Density Process and Results

G.3.2.1 Typical Application in a ECAC TMA

The results shown in Table 6-8 apply to a typical busy TMA sector, in this case a London TMA sector (EGTTWEL) around 2020. The sector starts around 5000 ft up to FL200. The size and shape of the sector changes with altitude. The results are therefore representative of information flowing through that test volume sector in the timeframe.

Although the study is technology independent, to illustrate how the results may be applied to assessing technology, the following figures have been produced. In practice a typical line-of-sight (LOS) communication system will have a designated operational coverage volume much larger than a sector. Typically at 5000 ft the theoretical radio horizon would be 87 NM and 194 NM at FL200 (assuming ground antenna at 0 ft).

G.3.3 ECAC Super Sector Density Calculation

The density number of the EGTTWEL test sector can be used to estimate the PIAC for the volume corresponding to several TMA sectors. The real PIAC for EGTTWEL and two adjacent sectors was calculated using SAAM and compared with the approach of applying the density number of EGTTWEL to the volume of the 3 sectors. It was found that the resulting PIAC numbers are similar, as long as the density numbers are used for the same type of sector (high density TMA, low density TMA, high density En Route, low density En Route).

The results obtained for the test sector need to be applied to a different airspace volume dependant on the technology considered.

G.4 Example Two (U.S. NAS En Route SV Density Calculation)

The NAS example was limited in that only En Route modelling was available. Therefore NAS results shown are strictly for the En Route domain.

G.4.1 Modelling NAS En Route

The results for the NAS were derived from an analysis of all existing En Route control sectors using 2004 FAA benchmark demand as applied within the Mid Level Model (MLM). The traffic was grown across NAS En Route sectors using existing Terminal Area Forecast (TAF) based demand scenarios. U.S. modellers performed runs of existing MLM scenarios for 2004, 2013, 2020 and then used regression analysis to obtain a 2030 PIAC distribution. The distributions developed are found to be similar to those for the ECAC calculation and for consistency the values shown in

G.4.2 NAS Traffic Density Process and Results

A similar process to that outlined above for the ECAC was used to achieve aircraft density. The En Route HD sectors for Phase 1 and 2 were identified by picking the sector with the highest PIAC distributions associated with Figure G-1. Atlanta Centre En Route arrival sector 19 had the highest PIAC in 2020, and was therefore chosen as the Phase 1 HD sector. Using an FAA tool, the spatial co-ordinates and lower and upper altitude floors of HD sector 19 were obtained. From this information, the volume and density of Sector 19 was calculated based on spherical geometry mathematics as in the ECAC calculation. Results are contained in Table G-1.

Sector Name	PIAC	Volume (nm^3)	Aircraft per nm3
En Route HD (ZTL 019)	41	7300	0.0056

Table G-1: Phase 1 NAS En Route Sector Density Calculation

G.4.3 NAS Super Sector Density Calculation

Sectors typical of 2030 operations are expected to be on the order of three times larger than current sectors. Since PIACs are not necessarily proportional to volume, separate PIACs for these ‘Super Sectors’ were developed. Table G-2 and underlying data showed a maximum sector PIAC of 52 aircraft in 2030 in the Atlanta Centre sector ZTL019. This was identified as the NAS En Route HD sector for Phase 2. Adjacent sectors to the En Route HD sector were chosen from those closest horizontally and vertically. The result was ZTL 016 and 020. These three sectors are actual En Route arrival sectors feeding the Atlanta Hartsfield Airport. Aggregating these three sectors resulted in an approximation of a sector three times the size of today’s sectors. The PIACs in 2030 for these sectors are shown in Table G-2. The following formulas were used to aggregate the three sectors.

ZTL 016 PIAC + ZTL 19 PIAC + ZTL 20 PIAC = HD Super Sector PIAC

ZTL016 volume + ZTL019 volume + ZTL020 volume = HD Super Sector Volume

Using these formulas, an aggregate PIAC of 95 and Volume of 31,996 nm^3 was obtained for a 2030 HD Super Sector.

Sector Name	PIAC	Volume (nm^3)	Aircraft per nm^3
En Route (ZTL 16)	22	9816	0.0022
En Route HD (ZTL 19)	52	7300	0.0071
En Route (ZTL 20)	21	14880	0.0014
Super Sector	95	31996	0.0029

Table G-2: Phase 2 NAS En Route Super Sector Density Calculation

G.4.4 Mapping the NAS En Route Super Sector

The selected HD Super Sector is highlighted on a map of NAS En Route sectors in Figure G-1, and Figures G-2 and G-3 show additional detail on the three sectors aggregated to represent the 2030 HD Super Sector.

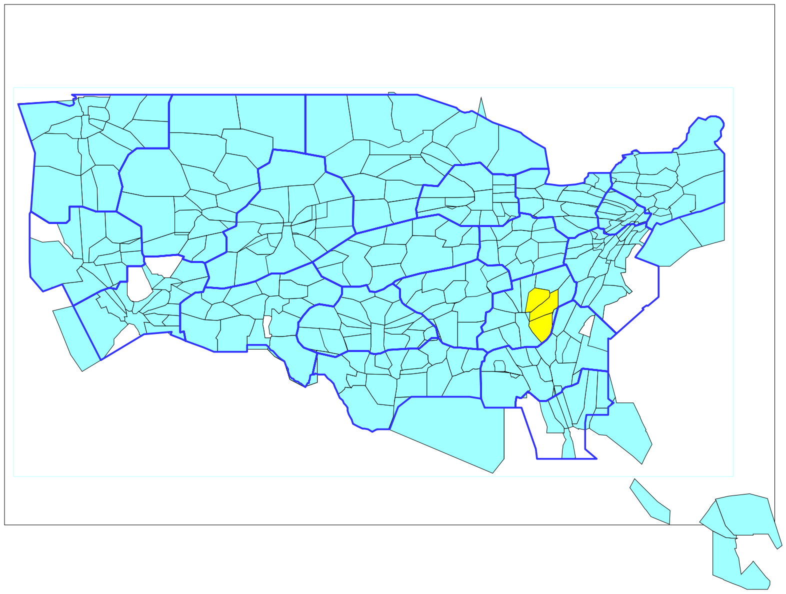

Figure G-1: NAS En Route Sectors

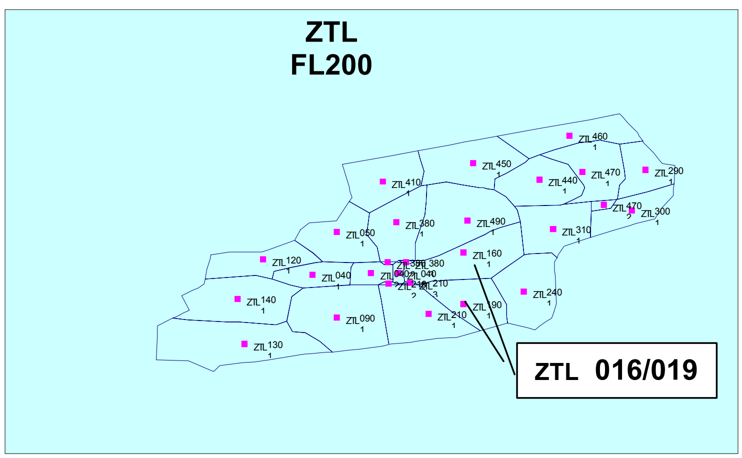

Figure G-2: NAS 2005 En Route Sectors ZTL 016 and 019

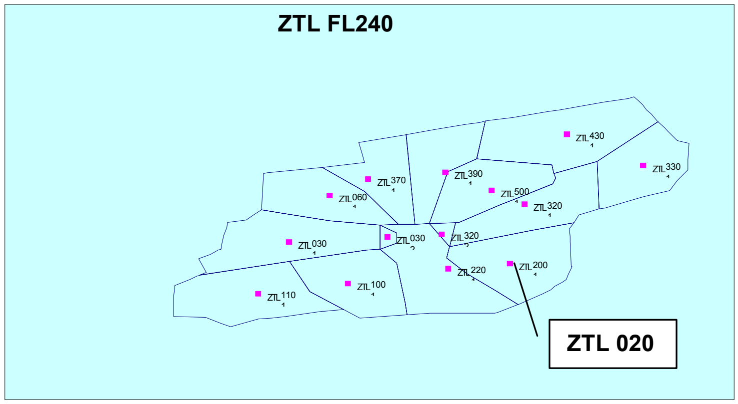

Figure G-3: NAS 2005 En Route Sector ZTL 020